

Guide to Active Vehicle Barrier (AVB) Specification and Selection Resources

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INTRODUCTION

This resource guide is intended to provide information to help engineers, policy makers, security managers, intelligence analysts, and other security professionals successfully determine Active Vehicle Barrier (AVB) specifications and select appropriate AVB models for a particular site requiring restricted access. The document presents an overview of AVB specification- and selection-related processes. It also provides an accompanying set of helpful resources, tools, and recommended practices gathered from the field to help professionals select AVB models that meet the desired specifications.

AVB specification refers to the determination of selection criteria for an AVB at a specific site. AVB selection refers to the identification of the best technology(s) to meet required specifications, when balanced against cost and additional selection considerations.

There are four main sections in the resource guide, each geared to assist users at different stages of the specification and selection processes. The four sections are:

1. **Site Planning and Design**—introduces planning activities leading to site design and works to create an understanding of the effect of site design on AVB selection and vice versa. Performance of the listed planning activities generates information in adequate detail to support determination of selection criteria used in AVB specification and selection processes.
2. **Determining Selection Criteria**—presents a compilation of selection criteria that have been employed to date throughout the security and AVB industries. Selection criteria provide an analytical framework to align or interpret needs (including operational requirements) into technology specifications across sites. Appendix A provides resources to help determine selection criteria values for a specific site.
3. **Writing Specifications**—helps structure specifications into a document that can be shared with manufacturers. It provides a link to a specification template example with the types of information and level of detail professionals should consider.
4. **Selecting Model Specifications**—offers a point of contact to obtain a searchable spreadsheet of model specification information. The intent of this spreadsheet is to serve as a starting point to identify and explore AVB models and then contact manufacturers to further assess potentially desired models. This tool provides the most benefit if used after determining selection criteria informed by detailed planning.

Crash-rated, active vehicle barriers come in a variety of:

Styles: bollard, gate, post, beam, wedge, net, and cable

Movements: raising, lowering, sliding, swinging, and folding

Drives: hydraulic, pneumatic, electric (including battery), friction / gravity-drive, manual



Electric Cable Trap. Source: RSSI



Portable Wedge. Source: B&B



Mobile Net Barrier. Source: NeuSecurity



Bi-Folding Speed Gate. Source: Eagle



Semi-manual Barrier. Source: PRO Barrier VolarX Barrier

This document is intended to serve as a companion to existing guidance and standards. All resources and practices should be carefully reviewed and selected or adapted to fit each project's needs.

1. SITE PLANNING AND DESIGN

This section provides an overview of planning and execution processes that support AVB specification and selection. Although the remainder of the report will focus on executing AVB specification and selection, it often refers to supporting processes that the reader should understand. Planning to employ AVB is appreciably more complex than planning to employ passive barriers, in part because AVB include moving parts, regularly interact with vehicles and pedestrians, and must also prevent access.

It is recommended practice to begin AVB planning with a set of activities that generate sufficient information on site conditions, boundaries stemming from policy and requirements, expected threat, and the intended site design. It is also recommended to start these activities long before AVB specifications are written. Coordinating planning for AVB selection with planning for overall site design may provide opportunities to select site and AVB design features that can potentially work together to control costs or increase performance.

Some organizations and agencies already have processes and tools in place to support AVB requirements determination. For those that do not, the United Kingdom (UK) Government Centre for the Protection of National Infrastructure (CPNI) uses an analytical framework consistent with these recommended practices. The framework can aid in defining Level 1 and subsequently, Level 2 Operational Requirements (OR). Operational requirements are statements of needs and form the basis for the development of technology specifications.

Level 1 OR are statements of the overall security needs, and they are a direct result of: assessments of perceived threat, the site to be considered, an asset's description, and an understanding of the consequences of compromise, perceived vulnerabilities, and success criteria.

Level 2 OR are more detailed statements of needs for suggested security solutions. If Level 2 OR for each component are met, then they will help develop Level 1 OR as an integrated security solution. The key is to identify Level 2 OR together to identify crucial dependencies and tradeoffs between various potential components. Level 2 OR relate to Hostile Vehicle Mitigation (HVM) considerations and address the use of vehicle barriers (CPNI, 2010a).

Operational requirements include items as detailed as the intended mode of operation and respective speed (e.g., cycle time, response time, emergency operation), expected traffic flow, and security screening considerations. The OR and resulting site design may need to be revisited and refined at later dates (1) to better align needs with available technologies during AVB specification and selection and (2) in response to future changes to the site layout or threat level.

CPNI's OR framework describes many planning activities. Figure 1 highlights the sequence of site planning activities especially important to supporting AVB specification and selection. The following subsections 1.1 – 1.4 further detail how these planning activities relate to AVB.

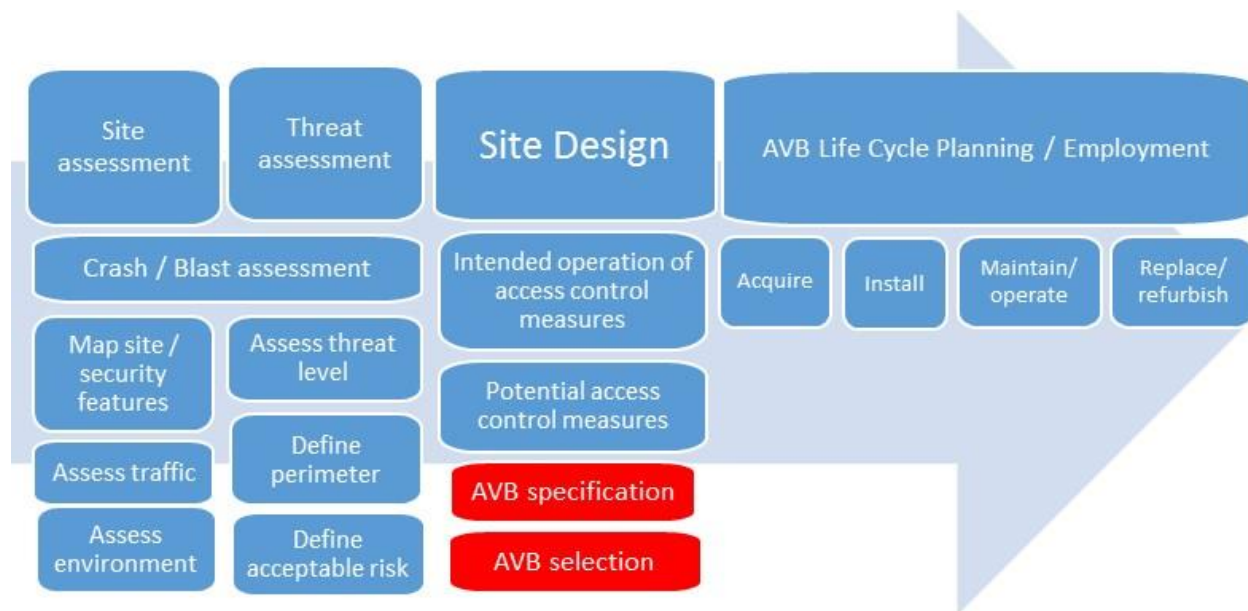


Figure 1. Integration of Site Planning Activities, Design, and OR in AVB Life Cycle.

1.1 Site Assessment

Perform a site assessment to provide information that ensures the selected AVB will fit into the existing or planned site, without penalty in performance or cost. A site assessment is a complete analysis of site physical characteristics, including roads, buildings, topography, and traffic flow. As such, it is critical to involve a wide range of Subject Matter Experts (SMEs). Site assessment includes conducting traffic engineering studies that determine expected traffic type (including pedestrian), peak volume, duration of peak volume, traffic patterns, and parking. A site survey should include preparation of a detailed and scaled map of the protected facility and surrounding topography to include major dimensions and descriptions of:

- structures, roads, terrain, and landscaping, (current and planned) security features, exits and entrances, and locations of critical infrastructure;
- a geotechnical survey;
- underground utilities and electrical diagrams;
- environmental constraints (e.g., drainage, temperature, pollution) and ground conditions (e.g., grade and surface type);
- and property perimeter.

Include on maps any features outside the perimeter that could possibly be used to reduce vehicle speed, prevent access to the perimeter barrier, shield structures from damage in the event of an explosion, or affect an aggressor's progress in any other way. Planned changes to surrounding roads or facilities should also be considered. Results of the site assessment identify opportunities, requirements, and constraints that impact site design (see section 1.3).

1.2 Threat Assessment

Perform a threat assessment to identify the possible threats or vulnerabilities that a particular site is subject to and provide information that ensures the selected AVB (in concert with other security features) defeats or creates delay for the expected threat. Threat assessment is a recommended practice for every organization. The Interagency Security Committee (ISC) provides a risk assessment process for federally owned buildings to determine a facility security level, with an (For Official Use Only [FOUO]) appendix that includes baseline countermeasures associated with facility security level (ISC, 2013). For organizations that inherit buildings or facilities for which threat assessments have already been conducted, a set of minimum security requirements with increased levels of protection selected on a case-by-case basis may be necessary. Analysis conducted by organizations should include a site-specific vehicle dynamics assessment to determine attainable vehicle speeds (to determine requirements for AVB crash rating) and blast analysis (to determine penetration and stand-off requirements).

A threat assessment produces information that directly leads to the development of mitigating measures, both material and non-material, designed to protect a site or facility. For example, outcomes from threat assessments are used to determine the necessary AVB crash ratings and to determine what AVB features are warranted (e.g., features that thwart complex or follow on attacks, motorcycle attack, tampering, emergency fast operation (EFO)). During threat assessment, decisions on levels of acceptable risk are made. Those decisions are taken into consideration during site design to balance security needs against safety and available resources. Site design or AVB selection considerations can lead to a reassessment of threat. A vehicle dynamics assessment is typically grouped in with threat assessment. It determines the necessary minimum crash rating for vehicle barriers to stop a threat, and the results provide a key AVB specification parameter. Results of the threat assessment together identify opportunities, requirements, and constraints that impact site design (see section 1.3).

1.3 Site Design

During site design, consider AVB specification and selection as a planning factor. Site design establishes a holistic physical security plan for a site. The site design lays out the composition and intended operation of access control measures,¹ to include an AVB, that together create an access control point, entry area, or security perimeter. The functionality of the site and access control measures, particularly operating procedures, must be described or understood during site design. Site design typically attempts to balance security, safety, and traffic flow to mitigate the assessed threat. To be successful, vulnerabilities, requirements, and constraints identified through threat and site assessments are addressed in the site design. For example, site drainage must be factored into the site design to avoid developing a collection point for debris from storm runoff. Improperly designed site drainage can also lead to the site becoming overwhelmed with water, which in turn creates maintenance issues as well as inoperability due to excessive icing. Site design planning often results in a change in the site itself (e.g., the

¹ Includes physical controls, operating procedures, hardware and software features used in various combinations to allow, detect, or prevent access (Unified Facilities Criteria [UFC] 4-022-02, 2009).

addition of lanes or relocation of entry points) to facilitate economies (i.e., to support cost savings) or better performance.

1.4 Whole Life Cycle Planning and Employment

Whole life cycle planning and employment involves understanding the implication of upstream decisions (e.g., specification and selection) on subsequent acquisition, installation, maintenance, removal, refurbishment and replacement activities. Considering life cycle planning promotes selection of an AVB that not only fits the site design and addresses the threat, but also controls cost to install, operate, and remove or replace the AVB. Some life cycle plans have expanded stakeholder consultation to coordinate across traditionally discrete planning stages. For example, some may include specification engineers in the development of maintenance contracts or in site design to identify the implications of site design decisions or suggest alternatives. Another trend, primarily in the U.S., is to employ life cycle planning considerations earlier in security site design.

2. DETERMINING SELECTION CRITERIA

This section introduces an analytical framework of selection criteria to help translate OR (i.e., project needs) into specifications intended for AVB manufacturers. The purpose of selection criteria is to narrow down selection to those barriers most suited to the site and intended operating procedures. However, manufacturers often stated that they have a high degree of flexibility to modify designs to a specific site, and that every model is essentially a site-specific design. Therefore, while some criteria may not distinguish between choices during selection, the selection criteria are still necessary to define in order to guide further refinement of the final selected design (and associated cost).

Section 2.1 introduces broad selection criteria categories. Section 2.2 details the range of potential selection criteria within each category, including their definitions and related terms. The selection criteria introduced here should be determined for each site. Appendix A contains additional information and resources to help professionals determine some or all of the selection criteria introduced here, using information gathered from site planning and design activities. Some selection criteria can be incorporated into specifications (see Section 3) and/or be used to less formally guide model selection (see Section 4).

2.1 Selection Criteria Categories

Selection criteria are organized into the broad categories described below.

1. **Physics.** Selection criteria in this category describe the ability of a barrier to stop a vehicle and to provide a credible perimeter to protect against Vehicle Borne Improvised Explosive Devices (VBIEDs). It includes AVB features or factors that affect the fundamental physics concepts underlying vehicle-barrier collisions and the effects of a VBIED. The factors which aid in determining the ability of a barrier to stop a vehicle include: vehicle speed (and acceleration), the type of vehicle, gross vehicle weight, impact angle, and subsequent kinetic energy absorbed. Because explosive forces and debris projection decrease rapidly with distance from the source², stand-off distance between the explosive/vehicle and targeted building/facility and susceptibility to debris throw from the vehicle or explosive are other important factors in this category.

Certification. This is a method to verify the physics related attributes. The specific vehicle barrier certification standards used to rate an AVB are an important consideration, for example, to understand testing features such as the axle loading or frame of the vehicle tested or the measuring method employed to determine vehicle penetration distance. It may include that barriers be certified by an independent, credible third party. Organizations may have (organization or country) specific requirements for what test methods are appropriate, for example based on the vehicles expected in that location. Some commonly used/accepted certification standards are those from the American Society for Testing and Materials (ASTM)

² Federal Emergency Management Agency (FEMA) 426. *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings: Providing Protection to People and Buildings*, Chapter 4—Explosive Blast; and FEMA 427, *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks*.

International, the Publicly Available Specification (PAS) from the UK, International Workshop Agreement (IWA) from the International Organization for Standardization (ISO), and the Department of State (DOS) ratings (pre- and post-2009, no longer in use).

2. Environment. Three environment aspects make up this category. First, there are environment features that can be used or altered to reduce the vehicle's approach speed, such as road surface conditions and the design of the vehicle's path (e.g., straight, curved, or banked terrain features). Locations with an urban landscape, nearby waterways, and unique architectural features may call for a different barrier design (e.g., due to potentially small standoff distances or historical preservation concerns). The second aspect of the environment that influences vehicle barrier design is impact of environmental and weather related conditions on the barrier itself (i.e., barrier longevity). Depending on the particular environment, barrier hinges, hydraulics, and surfaces may require protection from pollution, dirt, and debris, acidic or basic conditions (e.g. due to pollutant or marine environments), saltwater and sand (e.g., coastal and other areas), freezing or hot and humid climates, and rain. The third environmental aspect is related to the impact of the barrier on its surroundings (e.g., whether the barrier is made from materials that might be classified as environmental hazards, the impact of the barrier on underground utilities, barrier compliance with environmental regulations, and noise generated by the AVB during operation).

3. Physical. Attributes refer to all features related to the barrier's appearance or makeup. Dimensions (e.g., standard width and/or minimum height conforming to driveway or garage ramp, installation depth), construction material (e.g., concrete, steel), category/type (e.g bollard versus wedge), vehicle clearance or aperture, weight (axle load), control panel design, and aesthetic considerations are physical attributes. This category also includes power needs (required amperage and phasing) and the durability of materials used to fabricate the barrier.

4. Safety. This category includes features that can minimize the possibility of injury from active vehicle barriers (e.g., emergency override/manual operation, status indicators, safety edges, photocells). Injury may be due to intentional or accidental deployment (e.g., due to operator error, driver error, or equipment malfunction). Integrated safety features can also include signage and warning lights to alert approaching vehicles to the presence of barriers. The presence of a protective shroud is another safety consideration.

5. Security. Items under this heading include features that minimize the probability or impact of threat intrusion, and includes features such as cameras, gatehouses, anti-tamper devices, lighting, and security personnel.

6. Operation and control. This includes features that address functionality, including modes of operation (e.g., whether or not the AVB is to be operated as 'normally deployed'), and the type of control mechanism (e.g., pneumatic, hydraulic, electro-mechanical, manual). The type of control mechanism selected will depend on desired response and cycle times, screening process, vehicle cueing/traffic flow, and environmental considerations. Additional considerations in this category include emergency operation features.

7. **Cost.** The estimated cost of an AVB factors in costs of the barrier itself, installation, all supporting equipment and ancillary items (e.g., spare parts, manuals, operator training), and life cycle maintenance.
8. **Installation.** This addresses all installation considerations including ease of installation (e.g., time to install, manpower required for installation).
9. **Maintenance.** This includes the amount and frequency of maintenance required for continuous operation. Barriers require ongoing, scheduled maintenance for effective and continuous operation. Other maintenance considerations include length and type of warranty offered by the manufacturer, the availability of critical/relevant spare parts, and the ability to keep adequate numbers of spare parts on hand to facilitate speedy repairs. Maintenance may be addressed by the addition of design features, such as built-in redundancy (e.g., redundant hydraulic pumping unit system) or greater durability of parts.
10. **Training.** As with maintenance, effective barrier operation is further facilitated through operator training and the development of a competent level of understanding of operating manuals, including general knowledge of troubleshooting guidelines and repair procedures performed by technicians. Operators may require some training to perform minimal preventive care activities (e.g., clearing debris) and alerting technicians to other potential errors. The amount and frequency of training required for continuous operation will factor into costs and manpower requirements.
11. **Mobility.** Mobility needs are dictated by desired use. Multi-purpose use of the space where the barrier will be installed or the need to reduce cost and use a single, portable barrier at multiple locations or for special events will affect selection of a barrier that is permanently fixed, semi-fixed, or portable.
12. **Business characteristics.** This includes the place (country) of construction as well as other details that may impact selection of manufacturer. Users need to be aware that barriers constructed outside of the U.S. may conform to different standards. Those standards must be compared to U.S. standards to ensure that the barrier meets the identified need.

2.2 Detailed Category Selection Criteria

Table 2.2 takes the broad selection criteria categories described in subsection 2.1 and associates them with more specific examples of criteria, definitions, and related terms. These criteria were derived from a review of barrier crash testing standards and other open-source literature related to AVB design considerations. While references are made to crash test standards, the intent of the criteria is not to define, set or recommend standards or decide requirements. Instead, the intent of the criteria is to summarize the many factors that users need to consider in the development of specifications and other AVB planning activities.

Test standards use different methodologies and are updated periodically over time. Some of the more recent standards are the CWA 16221:2010, ASTM F2656-07, PAS 68:2013, and ISO IWA 14-1: 2013. One might still encounter barriers tested to previously used, ased now discontinued,

standards such as DOS SD-STD-02.01. The differences between the most recent standards are outlined in ASTM F2656-07 (ASTM International, 2007).

Table 2.2. Selection criteria and associated definition or related terms.

#	Category	Criteria	Definition and related terms
1	Physics	Impact test standard	The certification standard used (e.g., PAS 68, ASTM, IWA, CWA).
		Vehicle Type / Weight	The gross vehicle weight. Vehicle type includes the frame that can vary across models, as cars (C), pickups (PU), medium duty trucks (M), and heavy goods vehicles (H).
		Impact speed	The maximum speed attained by the threat vehicle at the point of impact (vehicle-barrier impact).
		Impact angle	The angle between the vehicle and barrier at impact as measured from perpendicular to barrier, which is zero impact angle. Maximum kinetic energy results from head-on collisions (zero impact angle).
		Impact condition designation	The performance outcome against a combination of test conditions, which can include various combinations of test vehicle weight, impact speed, and impact angle. See IWA, ASTM and PAS68 standards for variety of impact condition designations. Related terms include barrier rating, impact rating, kinetic energy rating, stopping force, certification levels.
		Penetration rating	Distance measured from the leading edge of the vehicle's cargo bed and the inside face (e.g., non-impact side) of the barrier after impact.
		Standoff distance	Distance between the vehicle bomb and the target building/facility. Also called setback.
2	Environment	Susceptibility	Susceptibility to debris throw (from the vehicle) following impact.
		Speed calming	Use or alteration of general terrain features (urban landscape, trees, architectural), surface condition and design of vehicle's path (straight, curved, banked) to reduce approach speed.
		Barrier longevity	Ability of barrier to withstand environmental and weather conditions to support continued operations (e.g. heat, dirt, humidity, sand, high water table).
3	Physical	Compliance	Ensuring compliance with environment regulations. Compliance can impact installation procedures, operation (e.g., fluids employed) and removal considerations.
		Dimensions	Barrier dimensions including height, width, and installation depth (i.e., foundation depth).
		Material	Material used to construct barrier.
		Category	Barrier type.
		Aesthetics	Specific physical features required to blend into the barrier's surroundings.
		Power	Power needs (e.g., required voltage and amperage based on country of installation) and phasing (single- or three-phase).
Post impact condition	Structural response of the barrier.		

SECTION 2. DETERMINING SELECTION CRITERIA

#	Category	Criteria	Definition and related terms
		Durability	Related to longevity, but focused specifically on the material used to fabricate the barrier (e.g., composites, recycled materials, other materials).
		Vehicle clearance or Aperture	Clearance: width provided to vehicles to pass through when in the “open” position. Aperture: spacing between bollards when raised prevents vehicle clearance, or when lowered allows vehicle clearance of some size.
		Weight (axle load)	When in the “lowered” position, the load the barrier is expected to sustain (after repeated use) and continue to function normally.
4	Safety	Common Features and Compliance	Barrier features designed to reduce injury to operator personnel and prevent accidental employment. Compliance with disability acts. Pedestrian and operator safety compliance, e.g. through protective features such as skirts. This also addresses Occupational Safety and Health Act (OSHA) requirements. Some organizations are required to use Surface Deployment and Distribution Command Traffic Engineering Agency (SDDCTEA) compliant safety scheme when utilizing AVBs at access control points. While pedestrians and vehicles are separate, persons (e.g. bicyclists) and animals (e.g. pets) remain safety considerations.
		Covering	Presence of a protective shroud (e.g., accordion style covering) to prevent local damage to the barrier. Coverings may also be used to reduce trapping hazard (e.g., fingers).
5	Security	Security	Features that preserve the integrity of the barrier system. Some examples of features that would provide security are plates fixed with security screws), features that provide tamper proofing, or making access point on the secure side of the barrier).
6	Operation and Control	Control Mechanism	Mechanism for controlling barrier employment (e.g., hydraulic, pneumatic, electro-mechanical, manual).
		Operating modes	The mode of operation is either an open or closed mode. This status can often be a function of the hydraulic design.
		Failure mode	The presence of a fail-safe/fail-secure status. (e.g., security of the site might be increased if barrier moves to the raised or closed position following failure (i.e. fail secure)).
		Cycle time	Normal operating cycle. Once activated, time to complete the open and/or close process (pass-through rate or number of cycles per hour). Affects the possible rate of traffic flow and is site dependent.
		Response time	Time to initiate employment (activation time) of barrier (e.g., time between operator’s command and barrier’s response to the command).
		Emergency operation	Emergency fast operation (EFO) (aka emergency cycle): Once activated, expedited time to complete the open or close process, using atypical operating procedures.
7	Cost	Cost	Estimated life cycle cost of barrier and all supporting systems (including installation and maintenance), which is site dependent.

SECTION 2. DETERMINING SELECTION CRITERIA

#	Category	Criteria	Definition and related terms
8	Installation	Time to install	Includes all installation considerations that impact time for installation (in the case of portable or temporary barriers, the time to install is more accurately described as a set-up time).
9	Maintenance	Maintenance burden	The amount and frequency of maintenance required to sustain operations.
10	Training	Training burden	The amount and frequency of training required to sustain operations.
11	Mobility	Portable	Describes whether the barrier is portable, temporary (semi-fixed), or permanent/fixed installation. (Note: a temporary barrier can be freestanding as well as semi-fixed)
12	Business characteristics	Country	Country in which the barrier was constructed.
		Company disposition	Details about the manufacturer that may impact decision to hire (small/minority business, trade embargos, listing as an “approved manufacturer”, past experience).

3. WRITING SPECIFICATIONS

This section contains an introduction to writing specification documents for AVBs, which purchasers can provide to manufacturers or general contractors to better communicate their needs (i.e., determined selection criteria). The first section highlights specific trends and recommended practices related to writing specifications, as heard from interviews. The second section introduces an example specification template that organizations can use to develop their own specifications. Organizations have developed templates to guide the writing of specifications, to identify the types of information, level of detail, and some common language to include in specifications.

3.1 Specification Trends and Recommended Practices

A good specification is one that is detailed and specific but not restrictive (i.e., flexible). Detailed specifications ensure identification of barriers that meet performance needs. However, more technical specifications can decrease the number of options and lead to unnecessary restrictions that add cost.

Interviews³ identified some common challenges to writing specifications: providing sufficient details, providing enough flexibility in specifications to adapt to site conditions or across diverse technologies, and sharing information or incorporating input from the manufacturer outside of statements of needs or requirements. Where policies direct choice of the cheapest barriers that meet requirements, there is an understandable push to ensure performance through the inclusion of more selection criteria as requirements. The recommendations below are related to allowing detailed and yet flexible specifications:

- Spend significant time up front providing specifications at the level of granularity that will align with the site's unique needs to improve overall quality.^{4,5}
- Adapt specification templates to suit organizational context (e.g. procedural and policy constraints or requirements), relevant threat context, and site-specific needs assessment.
- Adapt specification templates to suit site conditions and provide reasonable assurance that barriers meet as-tested conditions. There are three components that can be specified: the barrier (e.g. bollard or wedge), the foundation (e.g. anchorage and substrate), and the supporting features and technologies (e.g. controls). The common trend is to specify that the installed barrier meets as-tested specifications, in order to maintain the crash rating. The latter two should be tailored to the specific site, with input from manufacturers or qualified engineers that have been provided with the results of site and operational requirements assessments.
- Provide a comprehensive description of operational requirements, to include commonly omitted details on: the planned operating procedures or environment; level of use (i.e.,

³ List of interviewees provided in Section entitled "Interview Points of Contact (POC) List".

⁴ Robotic Security Systems Inc (RSSI). Personal communication, April 15, 2014.

⁵ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

peak traffic flows and frequency of operation); and including the expected operational availability/Mean Time Between Failures (MTBF).

- Define comprehensive selection criteria, but not necessarily as a set of specification requirements. An alternative is to provide some defined selection criteria as descriptions to the manufacturers (e.g., as information shared during site visits, through a scoping document (CPNI, 2010b)). Another is to provide some defined selection criteria to the selecting agents as additional considerations to balance against cost.
- Create open lines of communication to share information with manufacturers. Provide some information to manufacturers as descriptive or supporting documents or selection considerations. Providing site drawings and the intended operating procedures or function of the barrier is a common practice. Industry days, industry forums, and site visits allow stakeholders to communicate information and still control access to more sensitive information. Another example is to request information from the manufacturer, such as their past performance or references which match expected site conditions.
- Avoid unnecessarily restrictive language in specifications. Values appropriately specified for one site (or barrier style) may be inappropriately restrictive for another site or style. Maximize the use of performance, functional, or operational requirements (see Glossary) statements where possible, rather than technology-specific requirements statements. Use language based on justified site constraints or worded as “capable of meeting” some need or “no greater than/no less than” the site constraint.
- Establish organizational procedures to introduce flexibility into more specific requirements. If organizational policies drive more specific requirements, empower selecting agents to use site-specific exemptions with proper oversight and approval (e.g., by engineers). This will allow flexibility to respond to new knowledge after a specific requirement has been written, or to apply select standards that improve the quality assurance of some technologies but may not apply to all technologies capable of meeting performance requirements. This could be particularly useful for aesthetic considerations. While different aesthetic criteria do not necessarily increase cost, the purchaser would be empowered to balance aesthetic criteria in cases where they impose unanticipated cost or performance penalties.

3.2 Example Specification Template

The example specification template was derived from a comparison of several existing specifications to compile examples of topic areas, language, and metrics that occur across documents. The documents generalized from included: the UK Government Centre for the Protection of National Infrastructure (CPNI) Scoping Document, United States Army Corps of Engineers (USACE) Protection Design Center (PDC) (2008), Department of Veteran Affairs (DVA), and templates provided by DOS (Overseas Buildings Operations [OBO] Standard Specifications, 2012).

The example specification template may be downloaded from:

<http://www.cttso.gov/>

This example specification template is intended to aid the purchaser in communicating requirements to contractors in support of potential acquisition decisions. The specification applies to active roadway vehicle barriers (referred to afterwards as the “barrier system”), which includes power-assisted or manually deployed AVB.

Adapt the specification template to suit organizational context (e.g., procedural and policy constraints or requirements), relevant threat context, and site-specific needs assessment. The example specifications template is not exhaustive and should not be employed “as is.” The reader should use the example specifications template to develop their own, organization specific template. The reader should then use their own organizational template to write a further tailored specification for each project. The template uses an outline format and bracketed [] text to help guide the reader on how to tailor the template.

The purchaser can develop their own specifications template by:

- First, conducting planning activities and research to better understand relevant context and possible implications of specification decisions. The example specification is intended to be used in concert with the 2014 Guide to Active Vehicle Barrier (AVB) Specification and Selection Resources, which highlights planning activities and available resources.
- Second, identifying additional examples of specifications from projects or organizations with relevant context (e.g., similar federal, foreign, threat, facility purpose). Such specifications will provide useful comparisons to this template to highlight areas that should be considered further before adopting. Unique organizational or project context might lead users to adopt requirements very different from the examples identified in this template.
- Third, modifying the scope of the specification content included in the example template by deleting or adding numbered levels. Adhere to organizational standards when editing the example specification template. For example, always ask the following question: “Is each numbered section and subsection adding a requirement that the organization deems desirable and appropriate?” If the answer to that question is “No”, then delete that section or replace it with the appropriate substitute language.
- Fourth, modifying the content of the specification text, by filling in the bracketed language. A first pass should identify and remove bracketed specifications, typically selectable items, not appropriate or desirable to include as a requirement. The remaining bracketed content should then be defined or removed, and typically, on a case-by-case basis for each project.

4. SELECTING MODEL SPECIFICATIONS

AVB model selection is constrained by the user's awareness of what technologies and services exist. To increase awareness of barrier manufacturers, a searchable Crash-Tested Active Vehicle Barrier Selection Tool was created using Microsoft Excel. The spreadsheet allows users to search for potentially desirable AVB models that meet some specifications and then further explore models by contacting the known manufacturers.

4.1 Searchable Model Specifications Spreadsheet Intent

The spreadsheet is intended to be used after site planning, selection criteria determination, and specification writing has been conducted for an informed selection process. It is an initial, exploratory tool to enable limited, side-by-side comparisons of crash-rated, active vehicle barrier models to focus further research. The data is not sufficient to select the most suitable barrier.

4.2 Searchable Model Specifications Spreadsheet Use

The Crash-Tested Active Vehicle Barrier Selection Tool is available to download at:

<http://www.cttso.gov/>

First, the user can identify crash-rated, AVB models of potential interest by filtering values that meet a small subset of potential selection criteria. Second, the user can get a better understanding of the identified barriers by reading across all fields of available information. Third, the user can access additional information by clicking on Uniform Resource Locator (URL) links to the original specifications and manufacturer or supplier websites used to populate the spreadsheet.

The spreadsheet includes information on a select subset of potential selection criteria. The spreadsheet includes selection criteria for which data was more suitable for searching because it (1) was more consistently available across model specifications and (2) could be described in a standardized way (using quantitative or categorical terms).

The spreadsheet includes AVB models that are crash-rated, or engineered (not tested) to meet crash-ratings, as identified in the following resources (as of August 2014):

1. United States Army Corps of Engineers (USACE) Protection Design Center (PDC). 2014. DOD Anti-Ram Vehicle Barriers List. January 17, 2014. pdc.usace.army.mil/library/BarrierCertification
2. UK Government Centre for the Protection of National Infrastructure (CPNI). 2014. Catalogue of Impact Tested Vehicle Security Barriers.
3. Manufacturer websites, from manufacturers listed in sources #1 and #2

Additional literature search and manufacturer correspondence identified information related to the barriers. The list of models is not comprehensive and data changes. It is recommended that users contact manufacturers to request complete and up-to-date specifications, identify additional models of interest, and collect information on additional selection criteria.

GLOSSARY

This section contains a list of acronyms and terms commonly used throughout the report. It contains some working definitions for terms used in the report that lacked a formal, published definition. Working definitions have been derived from existing descriptions or definitions to match the study scope and usage of the term by interviewees.

Access control. The physical guidance of vehicles and/or people going to and coming from a space through judicious placement of entrances, exits, landscaping, lighting, and controlling devices (such as guard stations, turnstiles, etc.). (American Society for Civil Engineers [ASCE], 2006)

AVBs (Active Vehicle Barriers). Active vehicle barriers, or power assisted vehicle barriers (PAVB), have moveable components, and their systems can be operated manually or mechanically to allow or restrict vehicle passage. (American Public Transportation Association [APTA], 2012)

A vehicle security barrier that after installation can be operated either by personnel or powered equipment to change its position and/or deployed state. (ISO, 2013a)

An impediment placed at an access control point that may be manually or automatically deployed in response to detection of a threat. (Department of Homeland Security [DHS], 2011)

Crash-rated. (Working definition) The unit has been tested (not engineered or designed) using a recognized test method or rating system for vehicle crash testing of perimeter barriers. Rating systems are defined by some combination of the size, velocity, and angle of approach of the design vehicle and the allowable penetration distance.

DBT (Design Basis Threat). The adversary against which a utility must be protected. Determining the DBT requires consideration of the threat type, tactics, mode of operations, capabilities, threat level, and likelihood of occurrence (ASCE, 2006). A profile of the type, composition, and capabilities of an adversary. (ISC, 2013)

EFO (Emergency Fast Operation). (Working Definition) An emergency operating mode separate from the normal operating mode that typically overrides safety features. It allows faster operating times that would be too unsafe or costly to use normally.

K-rating. Kinetic energy rating for AVBs. (APTA, 2012) **Note: SD-STD-02.01 was superseded by ASTM F2656-07 (ASTM International, 2007).*

L-rating. Vehicle penetration distance rating for AVBs. (APTA, 2012) **Note: SD-STD-02.01 was superseded by ASTM F2656-07 (ASTM International, 2007).*

OR (Operational Requirements). Statements of needs based upon a thorough and systematic assessment of the problem to be solved and the hoped-for solutions. (CPNI, 2010a)

Passive vehicle barrier. A passive barrier has no moving parts. Passive barrier effectiveness relies on its ability to absorb energy and transmit the energy to its foundation. Highway medians

(Jersey), bollards or posts, tires, guardrails, ditches, and reinforced fences are examples of passive barriers (Unified Facilities Criteria [UFC] 4-022-03, 2007). Alternately, a vehicle barrier that is permanently deployed and does not require response to be effective. (DHS, 2011)

Performance standard. Specifies the outcome required, but leaves the specific measures to achieve that outcome up to the discretion of the regulated entity. In contrast to a design standard or a technology-based standard that specifies exactly how to achieve compliance, a performance standard sets a goal and lets each regulated entity decide how to meet it. (OMB Circular A-119, Feb. 10, 1998)

Physical security. The part of security concerned with measures/concepts designed to safeguard personnel; to prevent unauthorized access to equipment, installations, materiel, and documents; and to safeguard them against espionage, sabotage, damage, and theft. (DHS, 2011)

Recommended practices. (Working definition) A method or technique that has consistently shown results superior to those achieved with other means and that is used as a benchmark. It may be formal (e.g., safety in PAM 55-15) (SDDCTEA, 2009) or informal.

Risk assessment. A formal, methodical process used to evaluate risks to a transit system. The security portion of the risk assessment identifies security threats (both terrorism and crime) to the transit system; evaluates system vulnerabilities to those threats; and determines the consequences to people, equipment, and property. (Derived from APTA, 2012)

Setback, the distance from the façade to any point where an unscreened or otherwise unauthorized vehicle can travel or park. (ISC, 2013).

Site perimeter. The outermost boundary of a site, often delineated by the property line. (ISC, 2013)

Stand-off distance. A stand-off distance at which the required level of protection can be shown to be achieved through analysis or can be achieved through building hardening or other mitigating construction or retrofit (DHS, 2011). Or, the distance maintained between an asset, or portion thereof, and the potential location for an explosive detonation or other threat. (APTA, 2012)

Tradeoffs. (Working definition) Movements and compromises between cost and performance criteria.

Trends. (Working definition) Trends are information related to new or common technologies, features, threats, or operational or organizational practices.

Vehicle penetration distance. Maximum perpendicular distance between the VSB datum line and either: a) where there is $<90^\circ$ yaw and/or pitch of the test vehicle, the vehicle datum point; or b) where there is $\geq 90^\circ$ yaw and/or pitch of the test vehicle, the furthest part of the load bed (for N1, N2 and N3 vehicles) or furthest part of the vehicle (M1 and N1G vehicles), achieved either dynamically (during impact) or statically (post-impact), whichever is the greater (ISO,

2013). ASTM additionally grouped penetration distances into penetration classes of P1 through P4. **Note: terms used in vehicles testing are defined within each testing document and may vary by test method employed, e.g., between ISO IWA and ASTM.*

VS (**Vehicle Security Barrier**). A barrier used to prevent potentially hostile vehicular access to a site, which, depending on its type, might include as part of its design a foundation and/or operating equipment (ISO, 2013). Or, a passive or active physical barrier consisting of natural or man-made features designed to keep a vehicle carrying explosives at the required stand-off distance. This may or may not be coincident with a pedestrian barrier. (DVA, 2007)

INTERVIEW POINTS OF CONTACT (POC) LIST

This section contains a list of organizations and individuals consulted to gather information. Points of contact (POC) cover a broad range of AVB subject matter expertise (manufacturing, site security planning, acquisition, and standards or certification organizations) across different sectors (US government, non-US government, local government, and industry).

Table 1.1 lists the organizations contacted to gather information for this project. Some participated in interviews using the interview guide, denoted as “Contacted, Interviewed”. The remaining organizations shown in the table were contacted and given an opportunity to participate, but those organizations chose to provide more specific information (which did not follow the full scope of interview guide topics) or otherwise limit participation. Organizations contacted that identified themselves as having a minor or no role in AVB specification are not included in this list.

Table 1.1 Points of contact and contribution

Organization Type	Organization Name
<i>Contacted, Interviewed</i>	
US Government	Air Force Civil Engineer Center
US Government	Architect of the Capitol (AOC)
US Government	Department of Justice
US Government	Department of State, Bureau of Overseas Buildings Operations (OBO)
US Government	General Services Administration (GSA)
US Government	Naval Facilities Engineering Command (NAVFAC)
US Government	US Army Corps of Engineers, Protective Design Center (USACE PDC)
US Government	US Courts, Administrative Office (AO)
US Government	US Marshals Service (USMS)
Local Government	Capitol Police (DC) (responded by email)
Local Government	Smithsonian Institute
Local Government	Virginia Department of Transportation (VDOT)
Non-US Government	Canada, Physical Security Abroad (CSN)
Non-US Government	Singapore, Ministry of Home Affairs (MHA)
Industry	American Society for Testing and Materials (ASTM) and Texas A&M Transportation Institute
Industry	APT Security Systems
Industry	ATG Access Ltd
Industry	Avon Barrier Company
Industry	Broughton Controls
Industry	Delta Scientific
Industry	Elite Contracting Group and Rileen Innovative Technologies Inc

Organization Type	Organization Name
Industry	Heald
Industry	Highway Care
Industry	Marshalls Street Furniture
Industry	RSSI Barriers
Trade Association	Perimeter Security Suppliers Association (PSSA)
<i>Corresponded With, Not Interviewed</i>	
US Government	Army SDDCTEA (Surface Deployment and Distribution Command Transportation Engineering Agency)
US Government	Nuclear Regulatory Commission (NRC)
US Government	Department of Transportation, FHWA and Volpe Center
US Government	Interagency Security Committee (ISC)
Non-US Government	UK Government Centre for the Protection of National Infrastructure (CPNI)
Industry	American Public Transportation Association (APTA)
Industry	Concentric Security University

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APPENDIX A. DETERMINING SELECTION CRITERIA: ADDITIONAL RESOURCES

The selection criteria need to be defined for a specific site (for all potential barriers included) before they are used as specifications or selection considerations. This appendix supports determination of selection criteria by aggregating potential resources, including published resources, organizations, and current experiences from the security community.

To start, the reader should identify the policy and guidance that exists within their organization. It is important to understand project and organizational context to determine which guidances are appropriate to apply, and to distinguish between potential advisors (or subject matter experts) with the most relevant expertise. Then, the reader can begin to review published resources and stakeholders to determine on a case-by-case basis if they could contribute to determining selection criteria for a project. Appendix A provides some such resources to review.

The content of this section is organized by the selection criteria categories outlined in Section 2. Not all criteria categories are covered. One reason was that published resources that address that criteria in detail already exist. Another reason was that interviewees did not provide additional practices for that criterion. The Works Cited and Interview Points of Contact appendices outline sources of information that aided in the development of this section.

A.1 Published Resources and Reachback Organizations

Some organizations have established guides and standards for barrier selection. Tables A.1.1-A.1.3 include some examples of published resources that interview points of contact identified as useful to build knowledge in AVB specification. It includes a list of organizations and published resources along with a description of information they provide. Where possible, readings are associated with specific planning activities or selection criteria topics.

There is an increasing desire to recognize qualified subject matter experts to advise AVB specification and selection, or to develop in-house subject matter expertise. The classic approach is to build knowledge (e.g. demonstrate the right training or certification), and/or adequate experience (e.g. demonstrate a proven track-record). The most common recommendation from interviews was that experience is the best indicator of AVB specification and selection expertise, in particular to build field work and to collaborate with a diverse group of existing experts with a proven track record. Education can be a valuable asset to supplement experience.

Organizations have established training and certifications in areas of barrier selection, and some organizations provide consulting services or advice upon request. Table A.1.1 provides a list of organizations more often cited by interviewees as having special expertise in an area of interested or as providing training that indicates adequate expertise. The table does not include a review of security consultant professionals. For example, RSES is a certification that qualifies that an engineer has experience specific to areas of security such as vehicle barriers. However, to determine the most appropriate advisor, the reader should still request the past experience of

individuals to determine if their expertise matches project context and scope of the work to be advised.

Table A.1.1. Organizations providing reachback.

Resource	Description
ASTM International (formerly American Society for Testing and Materials)	Organization, multi-sector, that develops (by consensus) voluntary technical standards for materials, products, systems, and services. See www.astm.org/COMMITTEE/F12.htm
CPNI	Organization, provides awareness and training on the subject of designing-out vehicle-borne terrorism to architects, engineers, planners, and personnel with security, site ownership or operational responsibilities. CPNI also provide site-specific advice and maintain a list of tested counter-measures to several crash standards. CPNI classes include: CPNI Operational Requirements course, CPNI designing out vehicle borne terrorism (hostile vehicle mitigation) course; CPNI security surveys course; CPNI Detection systems, barriers & control of access course; CPNI CCTV & Lighting course. See www.cpni.gov.uk/advice/Physical-security/
GSA Advantage	A website maintained by the General Services Administration that provides support for acquisition with an online catalogue of barriers. It includes price quotes and some manufacturer information.
Manufacturers	Private entities that are able to provide advice ranging from specific aspects of planning or barrier design, to development of a turnkey solution. May include unpaid correspondence or advice, to paid services or training.
Register of Security Engineers and Specialists (RSES)	Register whose members are specialists in counter-terrorism design advice. This Register is maintained by the Institution of Civil Engineers.
Security Consultants	Various, none called out here. Able to provide paid consultancy ranging from specific aspects of planning or barrier design, to development of a turnkey solution.
(US Army) SDDCTEA	U.S. military engineering group that publishes detailed resources for access control point design, typically focused on safety and speed calming aspects, but placed in a relevant security context. See www.tea.army.mil/
(US Army) USACE PDC	U.S. military engineering group that publishes detailed resources for site design and AVB specification. USACE PDC maintains a list of ASTM tested counter-measures. See pdc.usace.army.mil/
Whole Building Design Guide (WBDG) Program	The WBDG website writes topical articles that review resources, or changes to resources, useful to site design and/or AVB selection. See www.wbdg.org/design/provide_security.php

Table A.1.2. Resources for Site Planning and Design.

Resource	Description
Site or Security Design	See Works Cited: (CPNI, 2014), (CPNI, 2011), (CPNI, 2010a), (CPNI, 2010b), (CPNI, 2009). CPNI lists updated periodically.

Resource	Description
	<p>USACE PDC website, UFGS/UFC documents (multiple referenced in Works Cited). The UFC 4-022-02 series (DOD 2013, 2009, 2007)⁶ and the Army Access Control Points (ACP) Standard Design documents (USACE, 2013) go into detail on several steps preceding specification, to include assessment methodologies and their relation to determining AVB specifications. The current UFC version includes additional site design examples, while previous versions include more detail on calculations, for example, to determine attainable vehicle speeds.</p> <p>Department of Homeland Security (DHS). 2011. BIPS 06/FEMA 426: Reference Manual to Mitigate Potential Terrorist Attacks against Buildings, 2nd Edition. www.dhs.gov/xlibrary/assets/st/st-bips-06.pdf.</p> <p>European Union, European Programme for Critical Infrastructure Protection (EPCIP). 2010. Reference Security Management Plan for Energy Infrastructure. ec.europa.eu/dgs/home-affairs/e-library/docs/pdf/2010_reference_security_management_plan_en.pdf</p>
<p>Specification and Selection Guides. Some policy and recommended practices.</p>	<p>CWA 16221: 2010 ISO IWA 14-2:2013 Vehicle security barriers part 2: Application (ISO, 2013) PAS 69: 2013 DOD 2013 UFC 4-022-02 (also see 2009 and 2007 versions) APTA SS-SIS-RP-009-12 GSA 2007 Site Security Design Guide</p>
<p>Risk assessment methodology and guides.</p>	<p>The Whole Building Design Guide website reviews risk assessment requirements and tools. (www.wbdg.org/resources/riskanalysis.php).</p> <p>Department of Homeland Security (DHS) 2012 Threat and Hazard Identification and Risk Assessment Guide.</p> <p>New York City Police Department (NYPD) 2009 Engineering Security: Protective Designs for High Risk Buildings.</p> <p>Federal Emergency Management Agency (FEMA). 2007. Site and Urban Design for Security: Guidance Against Potential Terrorist Attacks, Risk Management Series, no. 430.</p>
<p>Determine if the risk level requires specific countermeasures. Applicable to all federally owned buildings.</p>	<p>Interagency Security Committee (ISC). 2013. The Risk Management Process: An Interagency Security Committee Standard.</p>
<p>Examples of organization specific (or facility specific) guidance</p>	<p>American Chemistry Council. 2012. Alternate Security Program (ASP) Guidance for CFATS Covered Chemical Facilities. www.americanchemistry.com/Policy/Security/ACC-Alternative-Security-Program-Guidance-and-Template.pdf</p>

⁶ The relevant UFC series includes UFC 4-020-01 Security Engineering Facilities Planning Manual, UFC 4-020-02 Security Engineering Facilities Design Manual, UFC 4-022-01 Security Engineering: Entry Control Facilities/Access Control Points, and UFC 4-022-03 Security Engineering: Fences, Gates and Guard Facilities. The guides together cover a selection process to establish a protective barrier system around a DOD installation and designated restricted areas within the installation (enclave areas). A systematic approach is used.

Resource	Description
	American Society of Civil Engineers (ASCE). 2006. Guidelines for the Physical Security of Water Utilities. www.asce.org/uploadedFiles/ewri/Codes_and_Standards/4.pdf
	Customs and Border Protection (CBP). 2009. HB1400-02B CBP Security Policy and Procedures Handbook. www.cbp.gov/trade/rulings/directives-handbooks
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	Department of Veterans Affairs (DVA). 2007. Physical Security Design Manual for VA Facilities. wbdg.org/ccb/VA/VAPHYS/va_security_costs_dm.pdf
	Department of Veterans Affairs (DVA), Office of Construction and Facilities Management. Section 34 75 13.13, Active Vehicle Barriers. www.cfm.va.gov/TIL/spec/34751313.doc .
Examples of foreign or OCONUS requirements	Association Francaise de Normalisation. 2001. NFP 98 310:2001 Access Control Devices - Retractable Bollards - Characteristics and Performances of Automatic, Semiautomatic and Manual Retractable Bollards. ISSN 0335-3931. www.urbaco.be/pdf/Norme_NFP_98-310.pdf

Table A.1.3 provides a list of potential example publications to review related to selection criteria.

Table A.1.3. Publications for Selection Criteria by Category.

Category	Description
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<p>Physics (e.g. crash rating)</p>	<p>Standard test methods to determine crash ratings: ASTM F2656-07 PAS 68:2013, CWA 16221: 2010 ISO IWA 14-1:2013 Department of State SD-STD-02.01, Revision A, March 2003 Introduction by DOS staff to aid in determining crash rating, available upon request: Norris, Russell, Moffett, D., Inman, Jessica. 2012. The Basics of Anti-Ram and Impact Force: Perimeter Barriers. Department of State (DOS), Physical Security Division. [Available upon request].</p>
<p>Safety</p>	<p>SDDCTEA 55-15 Manual for Better Design of Entry Control Facilities. Provides a detailed overview of safety for vehicle barriers. ASTM International (formerly American Society for Testing and Materials). 2010. Work Item: ASTM WK31174 - New Guide for the Selection and Integration of Active Vehicle Barrier Safety Devices. www.astm.org/DATABASE.CART/WORKITEMS/WK31174.htm ASTM International (formerly American Society for Testing and Materials). 2012. Work Item: ASTM WK38052 - New Specification for Electronic Safety and Security for Closed Circuit Television (CCTV) Systems. www.astm.org/DATABASE.CART/WORKITEMS/WK38052.htm ANSI/UL325. Requirements cover doors, gates, and other such assemblies that include electric opening and closing appliances. DIN EN 13241-1 Industrial, commercial and garage doors and gates - Product standard - Part 1: European Standard. It specifies the safety and performance requirements for doors, gates and barriers, intended for installation in areas in the reach of persons. BS EN 12453:2001 recommends a minimum level of safeguarding against the crushing hazard at the closing edge of the gate.</p>
<p>Security</p>	<p>State Department Standard DOS SD-STD-01.01 Revision G Certification Standard Forced Entry and Ballistic resistance of Structural Systems. UFGS-08 34 01 (2009) Forced Entry Resistant Components: Guide specification covers requirements for forced entry resistant door assemblies, window assemblies, louvers, pass-through drawers, and prefabricated guardhouses. ISC, 2013: cites security standards applicable to countermeasures. For example: BRE 1175, ECBS/ENV 1300, BS EN 1143-1 1997, Underwriters Laboratories (UL) Standard 1034 NEN 1522: Material specification for bullet resistance. Applicable to attacks by hand guns, rifles and shotguns on windows, doors, shutters and blinds, for use in both internal and external locations in buildings. ANSI Standard 156.5-2001 American National Standard for Auxiliary Locks and Associated products ANSI A156.30 and ANSI Standard A156.30 2003, American National Standard for High Security Cylinders DIN 4102: Fire resistance</p>
<p>Environment (barrier longevity)</p>	<p>Electrotechnical Commission (IEC) 60034-5/60034-6 IP Code: Measure of intrusion of water and particles NEMA MG 1-2003. (E.g. NEMA 6 indicates equipment is submersible, water tight, dust tight, & ice/sleet resistant: Measure of intrusion of water and particles). ASTM Coating Performance D3359, B117, D714 & D1654, D2794, D822 D2244, D523: Requirements for levels of adhesion, corrosion, impact, and weathering</p>

Aesthetics	WBDG Aesthetics Subcommittee. 2012. Aesthetics (Overview). www.wbdg.org/design/aesthetics.php
	National Capital Planning Commission. The National Capital Urban Design and Security Plan: Designing and Testing of Perimeter Security Elements. www.ncpc.gov/DocumentDepot/Publications/SecurityPlans/DesignTestPerimSecurity.pdf
	Department of State (DOS), Bureau of Diplomatic Security's Physical Security Research and Development Branch. 2013. Perimeter Protection Streetscape Handbook. By Jodi La Coe, Zoltan Rado, and Jessica Inman. University Park, PA: Pennsylvania State U Larson Transportation Institute. Print.
Axle Load	AASHTO HB-17, Bridge Class 60 (military load bearing capacity), European Standard EN 124 DIN 1072: Measures determine the capability of equipment (e.g. bridge) to carry loads (e.g. fictitious vehicle classes). Sometimes adopted to describe load bearing capability of vehicle barriers. [Note: standard informally adopted but not intended for AVB]
Material (equipment components)	ASTM International (formerly American Society for Testing and Materials). 2013. ASTM F2200 - 13e1 Standard Specification for Automated Vehicular Gate Construction. DOI: 10.1520/F2200. www.astm.org/Standards/F2200.htm
	Department of Defense. 2013. UFC 4-022-03 Security Fences and Gates. www.wbdg.org/ccb/DOD/UFC/ufc_4_022_03.pdf .
Material Standards	Steel and aluminum standards cited from ASTM, AISI, AISC
	Section 09 90 00 PAINTS AND COATINGS; SDDCTEA Pamphlet 55-15 (e.g. ASTM Standards, BS EN ISO 1461): Overview of applicable standards for finishes
	AWS D1.1/D1.1M, BS 4872: Standards for welding
	UNI EN 13286-2:2005: standard for compacting index of the surrounding ground
	UNI EN 12620 standard- Class C25/30, Concrete with 10-30 aggregate: Standards for concrete
	ASTM C-94: Standards for concrete
Electrical	ACI (American Concrete Institute) 318: Standards for foundations
	Terminals and compression tools shall conform to UL 486A-486B
	EMC (ElectroMagnetic Compatibility) Directive (2004/108/EC)
	EC Machinery Directive (2006/42/EC). EU Machinery Directive: Harmonises the health and safety requirements for the design and construction of machinery at EU level.
	Low Voltage Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006: Safety legislation on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (codified version)
Software	SEIWG ICD-0101A and SEIWG ICD-0101B. SEIWG published XML standards for data interchange between control systems, and between control systems and sensors.
	ASTM International (formerly American Society for Testing and Materials). 2008. Work Item: ASTM WK20439 - New Guide for Interface of Active Vehicle Barriers and Automated Access Control Systems. www.astm.org/DATABASE.CART/WORKITEMS/WK20439.htm

A.2 Additional Recommended Practices

This section provides a snapshot of experiences in determining selection criteria, gathered from persons who manufacture or employ active vehicle barriers. This section includes additional recommended practices, trends, tradeoffs, and operational considerations associated with AVB

selection, based on a review of literature and interviews with organizations involved in AVB specification, selection, and employment. Where possible, trends and operational considerations identify the possible impact, challenges, and lessons learned for specification and proper operation of active vehicle barriers. Each organization should consult its own organization’s requirements, as some Services, agencies, or organizations will have specific requirements that differ somewhat from the recommended practices provided here.

Table A.2.1 summarizes key recommended practices discussed below, organized by criteria category and topic area. It summarizes AVB industry problems, recommended practices to address those problems, and expected outcomes from executing the recommended practices.

Table A.2.1. Summary of recommended practices.

#	Topic	Problem	Recommended Practice	Expected Outcome
1	Planning	AVB not designed for site-specific features	Consult with a variety of experts and conduct supporting analyses to plan site security and AVBs in a holistic manner (establish clear operational requirements)	Identify cost and performance impact of specific selection, installation and maintenance decisions.
2	Procurement	Selection of AVB based on lowest cost	Consider integrated design approaches	AVB design based on adequate integration expertise, installation and maintenance coordinated, improved barrier performance and longevity
3	Aesthetics	Barrier system seen as a negative impact on the community	Consult with experts in historic preservation and public space; consult CPNI Integrated Security Guide.	Minimized impact of barrier system on landscape and community residents
4	Selection of Manufacturer	Faults with barrier	Select manufacturers with extensive positive past performance ⁷	Quality AVB with extensive service from OEM beyond equipment purchase and installation
5	Safety	Unsafe conditions leading to incidents with innocent motorists and / or AVB operators / security guards.	Include safety in planning and design, using standards set forth in documents such as PAM 55-15; integrate safety features into AVB design	Minimize crashes, fatalities, injuries, mission distractions; protection from potential liability; help maintain efficiency of security personnel. ⁸

⁷ This recommended practice may exclude relevant (less experienced) manufacturers. This recommended practice emerged in response to concerns with the variation in manufacturer quality and experience and resulted in a range of practices intended to identify the experience and qualification of the manufacturer in relevant site specific contexts.

⁸ PAM 55-15 quotes estimates from the Federal Highway Administration: \$3 million for each fatality, \$63,000 for each injury, and \$2,300 for each property damage only (PDO) crash (SDDCTEA, 2009) (Secondary Source: Federal Highway Administration 2005)

#	Topic	Problem	Recommended Practice	Expected Outcome
6	Security	Barrier tampering	Locate support equipment on secure side; add tamper switches; remote monitoring	Reduce security breaches that might lead to barrier malfunction or premature deterioration
7	Installation	Malfunctions due to improper installation	For third party installers have the manufacturer present (sign-off) during installation; use extensive documentation; certified technicians; use experts for quality assurance/oversight	Less malfunctions/better quality AVB
8	Installation	AVB performance in site condition differ from testing conditions	Involve structural and other engineers in assessing site conditions and verifying structural integrity of materials	(More likely) performance expected from tested crash rating
9	Training	Operator injury, legal liability	Provide operator training, procedure manuals and checklists	Fewer incidents associated with operator error
10	Maintenance	Frequent failures with barrier components leading to high costs	Follow manufacturer's maintenance schedule; More detailed maintenance specifications and contracts; frequent inspections	Positive impact on barrier longevity; fewer replacements or refurbishments required
11	Other	Low quality AVB that only meets K/L rating	Develop detailed specifications	Quality AVB designed with user's unique needs beyond crash rating

A.2.1 Planning

As described in Section 1, the process of site design, which includes designing and selecting AVBs, requires a significant amount of planning and analysis. This includes the development of threat or risk assessments and site surveys, among other things, which determine statements of needs called operational requirements (OR). OR form the basis for the development of technology specifications.

A common theme echoed in interviews centered on the difficulties arising from lack of detailed planning necessary for engineers to produce detailed (but flexible or not restrictive) specifications. A number of recommended planning activities to support the development of more detailed specifications were to ensure proper timing and scope of planning activities, and conduct activities that provide adequate information, including: site assessment; threat assessment and blast analysis, vehicle dynamics assessment, integrated site design, and life cycle planning.

Time and scope planning activities early on:

- Make planning site-specific. Adapt site and barrier design based on requirements and guidance for that location. For example, guidance within the continental U.S. (CONUS) will be somewhat different outside the continental U.S. (OCONUS),⁹ in particular in the areas of: material or OEM (original equipment manufacturer) availability,^{10,11} training or number of local service providers, level of risk (and associated cost of man-hours), environment, and regulations (primarily in safety and security).
- Engage stakeholders in security, safety, project design and implementation risk assessments as early as possible. This early engagement with the stakeholders also facilitates the development of business cases and will help identify potential issues, associated costs and constraints. In doing this earlier, expensive problems can be averted later (CPNI, 2009).
- Identify all (necessary)¹² stakeholders with an interest in the operational security of the site early in planning process. Use a wide range of seasoned, multidisciplinary expertise to conduct sufficient analysis and support a comprehensive site design. Many stakeholders may need to provide information, without decision authority. Example recommendations for experts and analyses to include in the planning phase are:
 - Expertise integration. Identify all persons providing services and ensure input of adequate AVB expertise. Interviewees echoed the general lack of integration expertise among personnel responsible for specifying and selecting AVBs. For example, integration is typically the responsibility of the architect engineer (A&E) or general contractor (GC). A&Es tend to have general electric and engineering expertise rather than specialized AVB knowledge in all areas—design, integration, and installation. The GSA recommends training for A&Es to address these knowledge gaps.¹³ Involving security consultants in the initial planning process can support integrated design-build approaches to security systems.¹⁴ Expertise for AVB may be ensured through providing intended or potential AVB subcontractors with an opportunity to provide input early on.
 - Legal representation/compliance. Consult with legal representation when considering the installation of an active vehicle barrier system to ensure it complies with all local, state and federal laws (APTA, 2012) (UFC 4-022-02, 2009). Non-US laws will be country-specific, but will also require consideration.

⁹ Examples standards include Australian and New Zealand Standards [AS/NZS 3845: 1999 – Road Safety Barrier Systems]; NCHRP 350 and European Committee for Normalization (CEN)); France’s NF P98-310 standard; Kingdom of Saudi Arabia’s (KSA) Ministry of Interior HCIS Security Directives. (See Table B1.1 for example references).

¹⁰ Protective Security, Ministry of Home Affairs, Singapore. Personal communication, June 09, 2014.

¹¹ Physical Security Abroad (CSN), Canada. Personal communication, June 10, 2014.

¹² The number of stakeholders is not necessarily the objective. Rather, the multi-disciplinary nature of expertise is important. For example, discussions with Elite Contracting Group (13 June 2014) indicate that having too many stakeholders with decision-making power (versus providing expert input) can slow critical decision points.

¹³ General Services Administration. Personal communication, 24 June 2014.

¹⁴ Elite Contracting Group. Personal communication, 13 June 2014; and Virginia Department of Transportation. Personal communication, 19 June 2014.

- Architects. Because the installation of vehicle barriers can be considered to have a detrimental effect on urban communities users are recommended to incorporate the expertise of architects and others who are experienced in urban design, historic preservation, and landscape architecture (Hall, Douglas).
 - Engineers. Engineers support the identification of site and policy constraints that affect specifications. For example, involve CPNI or the U.S. Army Corps of Engineers, Productive Design Center / Protective Design-Mandatory Center of Expertise (PDC / PD-MCX) (SDDCTEA, 2009).
 - Local officials and community groups. Consultation with local officials may speed the process of getting formal approvals for placing a vehicle barrier at the intended site (NYPD, 2009) (CPNI, 2014). Consultation with local officials is also necessary for some design aspects such as street alterations. Other local consultants include representatives from utilities companies, counter-terrorism security advisors, and safety management officials, among others. Community groups often play a role in aesthetic considerations.
 - Expert organizations. Organizations such as CPNI have been formed to advocate good design practices and planning into the implementation of security measures. The National Capital Planning Commission (NCPC) has developed the National Capital Urban Design and Security Plan to provide guidance for security planning in the nation's capital that enforces good urban planning and design (Hall, Douglas). The GSA provides a security design guide that outlines security project team and expertise selection as well as test cases for ways to improve site security (GSA, 2007). There are many other organizations that can offer good practices for users in the AVB community, and readers should communicate with local government and industry contacts for recommended organizations with expertise most relevant to their site conditions.
- Reassess site design periodically, e.g., following major site modifications or a change in expected threat.
 - The most common recommendation on how to build organizational or staff experience in AVB specification and selection was to supplement education with field work, and to collaborate with a diverse group of existing experts with a proven track record to acquire further knowledge and experience.
 - Keep multiple lines of communication open. Interviews highlighted the diversity in methods and benefit of ongoing communication with stakeholders. Manufacturers often found that clients were not aware of the options available to them (available services, design flexibility, impact of operations and site constraints). They found that discussing the general intended operations of the entry control point through the life of the barrier provided opportunities to suggest features or services to review. Some prefer site visits to provide information outside of specifications. Some offer modified support packages to increase cost-effectiveness. Some prefer design-build or modifications to design-bid-build processes.

Site Assessment. Determine implications of site assessment on potential AVB selection. For example, site assessment information such as traffic flow analysis, vector analysis and layout of roadways can identify tradeoffs between levels of AVB performance and use of alternative access control measures (GSA, 2007). Site assessment can identify if site features would impose added installation, maintenance or removal costs given selection of specific AVB features or styles. Site assessments should:

- Conduct environmental assessments to identify necessary AVB features to operate in the environment (e.g., heaters/snow melts for hydraulics in cold climate; heat/humidity protection; dirt/debris in urban areas; salt water, sand and high water table in coastal or other areas).¹⁵
- Conduct site surveys and assessments that aid in determining the best locations for vehicle barriers based on considerations of road geometry and conditions (e.g., camber, crest, grade, surface susceptible to freezing or flooding, potential for high water tables) (EPCIP, 2010).^{16,17,18}
- Identify how desired performance of the barrier can accommodate traffic flow, vehicle speed, and axle load. Interviewees have noted sometimes extensive damage to barriers due to the frequency of vehicles traversing the barriers at high speeds (e.g., greater than 35mph).^{19,20,21} Certifications do not exist to validate what vehicle speeds a barrier can sustain. Therefore, communicating the results of traffic studies to potential manufacturers is an important step during AVB design and selection.

Threat assessment and blast analysis. Perform a risk assessment to determine types of threats, threat tactics, and level of protection required (Casper et al, 2011). A component of the risk assessment should entail a blast analysis or blast design to quantify the effects of the blast and determine the vulnerability and consequences of an attack on the facility (Hall, Douglas). This analysis is desired over selecting the easiest available location for a vehicle barrier or following a prescriptive design process based on misinterpretation of security requirements (Hall, Douglas).

Conduct a vehicle dynamics assessment. This assessment determines the necessary minimum crash rating for barriers to stop a threat and is a key specification parameter. It should be calculated for every site, as the threats and avenues of approach used to calculate results vary by site. Vehicle dynamics assessments should be conducted in coordination with determining the security perimeter. For example, site assessment can map features like critical

¹⁵ Carter, Steve. 2014. Protective Design Center, US Army Corps of Engineers – Omaha District. PowerPoint presented to the Vehicle Barrier Working Group.

¹⁶ Carter, Steve. 2014. Protective Design Center, US Army Corps of Engineers – Omaha District. PowerPoint presented to the Vehicle Barrier Working Group.

¹⁷ Interviewee noted the importance of considering depth of excavation (shallower is better) and being careful to not create a storm inlet drain out of the barrier. Architect of the Capitol (AOC). Personal communication, April 11, 2014.

¹⁸ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

¹⁹ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

²⁰ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

²¹ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

infrastructure to help define a minimum desired security perimeter during threat assessment. Simultaneously, this can allow for cost savings (e.g. greater allowable penetration ratings within AVB crash ratings), reduce risk (e.g. from debris), or allow design of layered security. Note that results from a vehicle dynamics assessment should be checked if site design leads to avenue changes.

Site Design. Activities should:

- Ensure sufficient site capacity while minimizing the number of barriers.
- Identify opportunities to save cost by employing passive barriers in place of active barriers, manual barriers²² in place of power-assisted, and reducing the use of features that may be unnecessary or incompatible with site conditions.
- Identify opportunities to employ speed calming measures to reduce necessary crash rating and maintenance; use sally ports or turnaround points to allow search but minimize traffic; relocate security perimeter; or relocate entrances and exits.
- Determine implications of other access control measures on AVB specification and selection. For example, different AVB features can be selected or correctly programmed to better work with surrounding features and operating procedures, if those are communicated to the manufacturer.
- Determine how to coordinate physical barriers and procedures in order to provide comprehensive perimeter protection (i.e. a continuous level of desired crash rating with no unacceptable gaps). It is important that the site design provides comprehensive protection across time and potential operating conditions as well, to: control access during normal, after hours, and emergency operations, following power failure or accidental impact; provide sufficient detection and response time for the deployment of active vehicle barriers; support intended security for non-vehicles (e.g. pedestrians); and protect guards (e.g. ballistics protection).

Life cycle planning. Life cycle planning should include conducting or considering cost-benefit analysis that addresses negative and positive benefits of the vehicle barrier (e.g., tradeoffs in reliability, longevity, environmental impact and protection level). It should also consider the complete range of potential costs (e.g., include costs other than just the barrier purchase, such as costs associated with planning, installation, inspection and maintenance, and future refurbishment and replacement) (Hall, Douglas). The analysis should consider various courses of action (COAs) for achieving the protection level desired (e.g., consider site alterations such as traffic calming and use of natural terrain features in addition to barrier systems). Planning should consider an integrated design approach to consider the barrier system from a holistic perspective.

²² Personal communication with APT highlighted the importance of proper consideration for the intended frequency of use of the barrier system, as this is a potential opportunity to using manual barriers as a cost savings.

A.2.2 Physics

Physics parameters (e.g. crash rating) are typically determined by planning activities (e.g. vehicle dynamics assessment). Relative to other selection criteria, they can be less subjective.

Interviewees observed that crash test methods change over time to incorporate improvements. It is therefore important for users to periodically check for updates, especially when starting new security projects. Users may also consider requesting manufacturer-provided updates as part of their contract. Example changes include the release of IWA 14-1:2013 and recent changes to ASTM F2656-07 penetration rating methods. There is not a formal recertification process, but qualified engineers can assess or test the installed design, to provide reasonable assurance that it meets new requirements (or retains it following impact, wear, and refurbishment).²³

- Consider cost impact of post-impact condition (i.e. barrier survivability) following accidental (typically lower force) and intentional crashes. Barrier survivability is more of a risk assessment because it depends on the probability and the consequence of impact. However, post-impact condition test data or manufacturer communication can indicate the cost consequence of an accidental (likely much lower than tested impact) or intentional impact. Manufacturers may design for survivability to minimize costly repairs, especially to prevent replacing a foundation and/or replacing the entire unit (foundation survives impact, modular design, sacrificial or survivable parts).
- While barriers tested to higher than required levels are often accepted, a cautionary note should be taken—different vehicles may be able to defeat the systems that have achieved a higher rating by submarining (i.e. going under a drop arm or beam) or fitting between structural elements that stopped the higher rated vehicle. Furthermore, a barrier designed to stop a larger vehicle may not be able to stop a smaller vehicle, for example, a rising beam gate stops a truck but might allow a car underneath it if the beam is too high.

A.2.3 Environment

Interviewees often commented that the specification and selection should ensure barrier performance within site-specific environmental conditions (humidity, acidic or corrosive atmosphere, rain, temperature, debris or particle load). It is expected that the end user will document and communicate the local environment to the manufacturer, and that the manufacturer will then recommend appropriate design features and finishes.

Performance in certain environments remains a common challenge area, particularly adequate drainage. Therefore, consider additional practices to: modify installation, operation and maintenance plans to maintain performance in local environment (e.g. site design to install on local high points for drainage or tie drainage into local sewage (multiple interviewees), modify snow plow routes,²⁴ modify to suite freezing temperatures or soil conditions not matching crash

²³ UK Government Centre for the Protection of National Infrastructure (CPNI). Personal communication, April 14, 2014.

²⁴ Walter, Samson. 2014. Royal Canadian Mounted Police. PowerPoint presented to the Vehicle Barrier Working Group.

test); perform opposite season tests for performance verification testing (PVT) (UFGS, 2009); have engineers designate the correct drainage size above the often-cited 4 inch diameter for heavy rainfall areas;²⁵ employ waterproof technologies, e.g. IP68 or above rated enclosures²⁶ or submersible motors; include weatherproofing during installation, e.g. weatherproofing wires.²⁷

Speed calming should be used where the site allows, or manufacturers should be made aware of the potential vehicle speeds to recommend suitable barrier design features. Otherwise, barriers are typically designed for vehicles to travel over them at slower speeds (e.g. less than 35 mph).²⁸ Suitability to speed of traffic is not typically specified by manufacturers. PAM 55-15 recommends speed calming to control speed and reduce wear. Manufacturers can advise features or styles more suitable to high speeds or throughput.

A.2.4 Physical

Physical selection criteria values are not necessarily generalizable across projects because they meet site-specific requirements. Generalizing physical criteria can unnecessarily restrict selection and impose added cost. Examples of recommended practices include:

- Establish specification and selection procedures to identify and balance trade-offs between dimension, speed, aesthetic, and cost. Engineers and architects should be consulted together to properly identify the impacts and trade-offs of design choices.
- Understand options to meet dimension requirements. One challenge to defining the width of a barrier is that added height or wider openings can result in slower barrier operating speeds and introduce risk of vehicle/motorcycles tailgating or entering alongside or hinder shipping/transportation (unless designed modularly or light). A second challenge is that the ideal width for a site may not be crash-tested; barriers are typically tested to only one or a few dimensions. One option is to use modular styles with controls that open selectable subsets of units. Another option is to accept the use of barrier widths between two crash-tested widths (not just larger or smaller). To avoid performance risk, however, purchase only those sizes that have been tested and certified.
- Allowable gaps are fairly well standardized. Where pedestrians must have access, ADA requires access by disabled persons and that has been typically interpreted as gaps greater than 3 ft. Otherwise, spaced to meet barrier crash-tested testing conditions and to prevent threats from passing through gaps between the barrier and surrounding features.
- Aesthetics. Aesthetics concerns are very subjective and can vary widely from site to site (i.e., not all architects appreciate the same art forms). Considerations can include architecture and historic preservation, as well as noise levels. Concern over noise levels have led some users to make design changes associated with AVBs.^{29,30} The primary idea

²⁵ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

²⁶ ATG Access Ltd. Personal communication, June 04, 2014.

²⁷ Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

²⁸ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

²⁹ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

³⁰ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

behind aesthetics is to minimize the negative impacts of the barrier system on public perception. This can be accomplished in part by ensuring that appropriate experts in historic preservation and public space are made a part of the design process. *PAM 55-15* recommends that, “The aesthetics and design of the barrier system should be consistent with the installation’s exterior architectural plan and the surrounding architectural and landscape features” (SDDCTEA, 2009). Additionally, the GSA suggests that security projects “should include design and security elements that are in harmony with the surrounding architectural and landscape context (GSA, 2007).

- Consider maximum potential axle loads based on maximum expected size of vehicle (including emergency and construction vehicles). Load capacity is sometimes described in specifications using borrowed terminology such as DIN1072, Bridge Classes. Additional considerations for axle load are flush installation, and speed of traffic. Easily move/removed barriers or modular operation (through operating controls or barrier styles) are other features to consider to accommodate bulky or unexpected vehicle sizes.³¹

A.2.5 Safety

Active vehicle barriers pose a number of safety concerns for operators as well as innocent motorists. Those safety concerns can be mitigated through a variety of recommended safety practices. A fair amount of documentation exists on developing and maintaining safety at access control points/entry control points and specifically for vehicle barriers. Common recommendations include the following:

- To minimize injury to guards, barriers should not be installed immediately adjacent to guard posts. Users should consider keeping vehicle barriers as far from guard posts as possible (APTA, 2012).
- Single barriers should not be positioned in a way to attempt controlling multiple lanes of traffic (SDDCTEA, 2011).
- If a normally open (allows traffic through) operation is selected, there must be sufficient distance between the guard and the vehicle barrier to allow activation and closing of the barrier (RMIA and JBS, 2009).
- Installation of safety devices is recommended to prevent activation either by operator error or equipment malfunctions (APTA, 2012). Safety devices include warning devices to mark the presence of barriers, with appropriate warnings and notifications to approaching vehicles, vehicle detector safety loops,^{32,33,34} and road plates checkered for good traction.³⁵

³¹ Virginia Department of Transportation (VDOT). Personal communication, June 13, 2014.

³² During the VBWG, multiple participants noted that it was important to combine optical and loop detectors (or otherwise redundant sensors) in the vehicle barrier’s detection zone due to inherent flaws of each detector type when used alone. Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

³³ Interviewee noted that current vehicles are designed using fiberglass and polymers, and do not contain enough metal to set off the magnetic safety loops. As a result, sometimes the barrier does not activate. In his experience,

- Due to potential dangers associated with AVB activation and potential for false alarms, it is recommended that activation not be triggered through automatic detection and response. Instead, the control systems should be based on the actions of the security personnel manning the entry control facility (ECF) (e.g., via the use of push buttons and/or hand operated switches) (SDDCTEA, 2009).^{36,37}
- During maintenance or when barrier become inoperable, the ISC provides recommended maintenance response time (allowed duration of inoperability) commensurate with the assessed threat level (ISC, 2013). In addition, during inoperability, recommended practice is to employ temporary barriers that are manned, include over-watch measures (e.g. CCTV³⁸) paired with security response, or employ additional security measures such as manned chase vehicles parked on-site.³⁹

For more detailed safety-related practices and recommendations see the following references:

Pamphlet (PAM) 55-15. Army Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA) executes DOD’s transportation engineering program on behalf of the military services. It offers training and education as well as engineering services to support its mission to “improve highway safety and reduce traffic congestion on DOD installation roads and on routes providing access to installations.” PAM 55-15 provides a list of supplemental safety-related resources in Section 1.2.4. Design Guidance (page 1–4) (SDDCTEA, 2009).

A.2.6 Security

Security considerations include but are not limited to the following:

- Locate barrier support equipment (e.g., hydraulic power systems, generator, batteries etc.) on the secure side and away from guard posts to lower the threat of sabotage and injury to security personnel (Kessinger, Richard) (RMIA and JBS, 2009) (Department of the Army Headquarters, 2010).
 - Other alternatives include housing support equipment in heavy duty, lockable steel enclosures or inside other secure structures where they are afforded a level of physical protection. Housing structures also facilitate performing maintenance or repair without exposing personnel to bad weather conditions.

radar technology tended to work better than the magnetic safety loops. Architect of the Capitol (AOC). Personal communication, April 11, 2014.

³⁴ Also noted the need to stack two beams to improve detection accuracy in some situations. Civil Engineer, Smithsonian Institution. Personal communication, March 26, 2014.

³⁵ PAM 55-15

³⁶ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

³⁷ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

³⁸ The Interagency Security Committee provides additional guidance on the selection of CCTVs and other security measures. (www.dhs.gov/sites/default/files/publications/ISC_Risk-Management-Process_Aug_2013.pdf.)

³⁹ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

- For barriers that are expected to be left unattended or are located in remote or unsecured areas, continuous monitoring can be provided, e.g. by physical protection and tamper switches connected to a central alarm station (Kessinger, Richard) (RMIA and JBS, 2009) (Department of the Army Headquarters, 2010).
- Following installation of barrier, regularly review the site for changes to surroundings that may create alternate routes for new threats (e.g., demolition of a neighboring building may provide a route for bypassing an existing barrier or create some other vulnerability in the security system) (CPNI, 2014).

For more detailed security-related practices and recommendations see the reference list in Appendix A.

A.2.7 Operation and Control

The operation and control features of an AVB are important considerations. Unfortunately, the details of these features are often missing from barrier specifications. The sequence of operations anticipated should be discussed and incorporated in the design. This will help to ensure that cycle logic is not complex for operators' intended use.⁴⁰ Additional recommended practices are:

- Operating modes and controls should be defined for all potential operating procedures (e.g. normal, emergency, accidental impact, power failure). Planners have a responsibility to communicate intended operation of barriers and surrounding features to manufacturers. It is not safe to assume that the standard barrier design was made to fit your intended operation. Manufacturers are able to easily modify designs to fit most scenarios, but only if they are aware of the intended scenario. Operators have responsibility to document, train, employ, and update procedures—this is especially important at sites that include unlike barriers or where staff turnover is high.
- Operating speed should accommodate traffic flow and intended operational procedures (e.g. search procedures). Traffic engineering studies should provide the peak throughput and duration.

Typical time requirements are between 3 and 12 seconds to move from a full down position to a full up position to satisfy security requirements and control normal traffic flow. High normal operating speeds are not always necessary, e.g. lengthy search procedures or low traffic flow.

100% cycle duty means a barrier can run continuously without overheating (cycle every 8 seconds for example) and is intended for high throughput. It is not an assurance of low maintenance - higher throughput can still require higher maintenance for other reasons. Less than 100% duty cycle (e.g. above 30%) can be sufficient for most levels of throughput (or use of manual drives for low levels).⁴¹

⁴⁰ General Services Administration. Personal communication, 24 June 2014

⁴¹ Avon barrier Company (ABC). Personal communication, June 11, 2014.

- Where risk assessments determine a need, the barrier should also have an emergency operation feature that is capable of raising the barrier to the up position in a shorter time period, which is typically between 0.6 to 3.0 seconds (Kessinger, Richard). EFO should be driven by security requirements and are not always a necessary feature.⁴²

A.2.8 Installation

Many issues regarding installation of vehicle barriers are typically associated with quality control. Primary issues and actions recommended to address those issues include:

3rd party installation. Sometimes to save on costs or for other reasons, users elect to have AVBs installed by third parties (i.e., someone other than the manufacturer). In some cases, this action has led to issues with the overall quality of the AVB. To address this issue a recommendation is to use certified installers and technicians directly from the manufacturer or have the manufacturer sign-off once the installation has been completed to ensure that the barrier has been installed to the manufacturer's specifications and to ASTM (or other) standards (The Arrestor, ProBarrier Engineering LLC).^{43,44} Other recommendations to ensure quality installation by third parties includes use of:

- Experts who can ensure that the appropriate materials and procedures are being used (e.g., concrete strength, reinforcing steel, welding as tested)
- Construction crews, as their expertise is critical for excavation and other similar activities.
- Thorough documentation of the installation (to include photos, forms, and drawings) to support manufacturer sign-off.^{45,46}
- More detailed specifications to add manufacturer oversight as a requirement.
- Quality assurance representative present during installation.⁴⁷

Site versus Tested Conditions. Site conditions are rarely the same as the conditions in which the vehicle barrier was tested. While agreeing that the barrier (e.g. wedge or bollard) should be specified as tested, several interviewees recommended that engineers (with references or documented history in this task) be involved in an appropriate adaptation of the barrier foundation to support installation and maintain its crash rating performance and consider additional practices to document modifications and have manufacturers sign off on them.⁴⁸ Substrates other than that tested can impose additional site survey and installation challenges and can increase cost of installation (Total Barrier Works, 2010). For unknown substrate (e.g. in expeditionary or temporary events), engineers may need to also assess the substrate

⁴² APT Security Systems, Broughton Controls, and Highway Care. Personal communication, June 10, 2014

⁴³ Richard Kessinger, CPP. *From Jericho to Jersey Barrier*, CBRNE Terrorism Newsletter.

⁴⁴ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

⁴⁵ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

⁴⁶ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

⁴⁷ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

⁴⁸ APT Security Systems, Broughton Controls, and Highway Care. Personal communication, June 10, 2014; American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

composition through site drawings or core samples and then determine the appropriate anchorage requirements to maintain the crash rating.⁴⁹

Other recommended practices related to installation include the following:

- Ensure barrier is compatible with the available power source and with other security equipment installed at the selected site (e.g., perimeter intrusion detection and CCTVs).
- Ensure that leasing requirements are well understood prior to installation. One interviewee noted that they have moved toward use of shallow-depth barriers (i.e., use of wedge barriers instead of bollards) to ensure adherence to leased facility requirements.⁵⁰
- Make specifications more detailed to address non-performance aspects of barrier, such as specifying the desired grade of stainless steel,⁵¹ having original equipment manufacturer or agents they train and verify as proficient install and conduct upgrades, and non-outsourcing of components (i.e., use of single source for parts, pre-assembled in the factory to ensure components fit).⁵²
- Review documented lessons learned outlined in barrier review reports.^{53, 54, 55}

A.2.9 Maintenance

Ensuring proper maintenance, while acknowledged as important to performance and cost, appears to remain a challenge area. Maintenance of the barrier was most identified as driving the life cycle cost of the barrier, attributed to the collective cost of preventive and normal corrective maintenance, emergency repair due to intentional or accidental impact, barrier malfunctions and sometimes to the need for earlier-than-expected replacement due to poor maintenance or refurbishment. For example, many interviewees agreed that the difference in cost between a M30 and M50 barrier is generally less substantive than the life time cost associated with maintenance of the barrier. For example, one interviewee found that the lack of proper barrier maintenance for just a few years was absolutely detrimental and required removal or replacement of barriers.⁵⁶

Most manufacturers provide maintenance contracts that outline maintenance schedules and procedures to support continuous operation of the barrier as well as lists of spare parts and their supply source. Recommendations for what to include in maintenance contracts are details regarding routine inspections, adjustment, cleaning, pressure checks on hydraulic systems, and replacement of worn parts. Standards for the levels of wear that requires parts replacement do

⁴⁹ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

⁵⁰ OBO/CFM/SM/SCD/SEB, Department of State (DOS). Personal communication, March 20, 2014.

⁵¹ Civil Engineer, Smithsonian Institution. Personal communication, March 26, 2014.

⁵² Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

⁵³ General Services Administration: Edward A. Garmatz Federal Courthouse Dsc1200 Em Barrier Review

⁵⁴ General Services Administration: Camden Federal Courthouse Barrier Review

⁵⁵ General Services Administration: Trenton Federal Courthouse Barrier Review

⁵⁶ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

not exist and will likely be based on manufacturer or expert recommendations. Additional considerations prior to acquisition are to:

- Ask for and review cycle test results, including testing conditions. These give a sense of maintenance requirements and life cycle, but it can add cost to the barrier and is perceived as a maximum, not likely, capacity because test conditions do not match normal wear condition (vehicle throughput, accidental impact, lack of maintenance, corrosive environment).
- Evaluate designs for ease of maintenance. Determining level of effort (cost) up front remains a challenge. Manufacturers and persons who have employed a particular style of AVB and particular maintenance regimes can offer rough estimates of costs. However, emergency repair is not typically included in estimates of cost or maintenance regimes and should be additionally considered. Some manufacturers design AVBs from a modular perspective to facilitate replacement of parts (rather than replace foundation).⁵⁷ Others design AVBs to withstand the potential wear and tear from poor maintenance and/or accidental impact.⁵⁸ Finally, other manufacturers design AVBs to have lower fail rates or greater durability.⁵⁹ Consider keeping drive components where they are easily accessible (e.g., above ground hydraulic units).⁶⁰
- Consider frequency of use. Consider the usage factor in the determination of the warranty length.⁶¹ An extended warranty might be necessary for users who expect frequent use (e.g. 3000 cycles/day). For others, requiring less frequent use, an extended warranty may be an unnecessary expense.
- Consider refurbishment and recertification. Refurbishment needs can be included as part of operational requirements. These needs should also be communicated to manufacturers to support the selection process and accurate life cycle costing. Some AVB models are designed to be modular in anticipation of refurbishment (e.g., allowing a barrier to be removed and replaced with another barrier without significantly disturbing the foundation).

The refurbishment process, while executable, has raised a question in the AVB community. The question is whether the refurbished barrier will meet the same crash standards. Currently, there is no formal recertification to address this concern (i.e., it is a subjective call on determining the point at which a barrier needs to be recertified). However, a recommended practice is to have certified engineers assess the refurbished barrier and conduct field tests to provide assurance that the barrier still meets crash standards.⁶²

⁵⁷ ATG Access LTD. Personal communication, June 04, 2014; Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

⁵⁸ Avon barrier Company (ABC). Personal communication, June 11, 2014; ATG Access LTD. Personal communication, June 04, 2014.

⁵⁹ APT Security Systems, Broughton Controls, and Highway Care. Personal communication, June 10, 2014.

⁶⁰ Civil Engineer, Smithsonian Institution. Personal communication, March 26, 2014.

⁶¹ Marshalls Street Furniture. Personal communication, 25 June 2014.

⁶² Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

- Ask for guarantees. Manufacturers often provide longer warranties. It is also important for users to consider the time lapse between AVB selection and actual delivery/installation of the AVB—request that the warranty begin upon installation to avoid loss of warranty time.

Although maintenance schedules (or regimes) are commonly provided, interviewees report that users do not follow the maintenance schedule (attributed to a variety of reasons, including lack of budgeting up front, expertise, willingness to maintain, enforcement). Interviewees also recommended activating barriers every 24-48 hours, especially if normally lowered, as barrier failures have been associated with dormancy as well as repeated use. Another source noted that reliability data from manufacturers showed less than a three-percent failure rate when barriers are properly maintained (APTA, 2012).

While there may be issues with users adhering to maintenance schedules, there can also be issues associated with the maintenance activities that manufacturers themselves are performing. Therefore it is important for users to understand the details of the maintenance contract. The Center for Protection of National Infrastructure (CPNI) and others recommend that users address questions similar to those below to develop maintenance-related operational requirements (CPNI, 2010a) (CBP, 2009):

- Are the contractors approved by the supplier of the equipment?
- Is there system documentation readily available? (drawings, program listings, instructions and operation and maintenance manuals and logs)
- Are there logs to be kept for commissioning and subsequent performance tests?
- Is there a process for fault logging and resolution?
- How many times per annum are the barriers maintained by the contractor/installer/company? And, what specifically is checked during these visits? (do inspections include activities such as checking magnetic safety loops and other detection and safety features of the barrier)
- Do they look for deterioration, corrosion, degradation, debris, hinge fixing, screw fixings?
- What maintenance should be carried out over the life cycle? Has this been agreed?
- What is the contractor's call out or response time for an emergency? Is it stated that they must resolve the problem in a given time?
- Is there a maintenance log? Does it include repairs, replacements and system adjustments?
- Are there on-site spares? Spare parts and supplies should be stored in a documented location to ensure that barriers are quickly returned to full operation. Manufacturers should have a recommended spare parts package, for example, to facilitate at least 1 year of normal operation (DOT, 2004).⁶³

⁶³ Protective Security, Ministry of Home Affairs, Singapore. Personal communication, June 09, 2014.

Additional maintenance related recommendations include the following:

- Identify recommended practices associated with specific barrier types. Manufacturers are typically willing to provide additional training, documentation, warranties or advice—access to information is not a barrier.
- Provide operating systems (e.g., backup generators or manual override provisions) to ensure continued operation of active vehicle barriers during both standard and non-standard operations (e.g. to operate in the case of power failure, equipment malfunction, accidental impact, security challenge, emergency operations, and normal operation) (RMIA and JBS, 2009).
- Communicate to potential manufacturers if a high cycle rate or traffic flow is anticipated (RMIA and JBS, 2009). Features are available that allow higher cycle rates (e.g. greater amperage motors, increased frequency of maintenance).
- Communicate to potential manufacturers if the environmental impact from hydraulic fluid contamination is a concern (RMIA and JBS, 2009). Features are available that are environmentally friendly, such as electric drives or hydraulic drives with biodegradable oils.
- Development of a standard statement of work (SOW) to address the current variability in maintenance contracts from different manufacturers. Introducing a common language is expected to improve quality across the maintenance field.⁶⁴ Some consider creating a maintenance regime and structuring service contracts with manufacturers to match the expected life of the barrier.⁶⁵
- Communicate to potential manufacturers if a third party may be used for maintenance later on. While manufacturers typically maintain barriers during warranty periods, following expiration users may then maintain diverse barriers using in-house expert staff or third parties. Manufacturers may offer their services, or offer to prepare guides or help train staff to ensure barriers are maintained properly.⁶⁶ USACE PDC has worked with other organizations to develop an example of a thorough maintenance guide to adapt or adopt after AVB warranties expire (Vehicle Barrier Maintenance Guide, 2007).⁶⁷
- Include more detailed specifications and/or maintenance contracts to address things such as rerouting snow plows away from bollards, not using salt or sand near bollards (it falls into openings, and becomes corrosive to the barrier), and having engineers re-inspect barriers following incidents to assess second-attack readiness.

⁶⁴ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

⁶⁵ Protective Security, Ministry of Home Affairs, Singapore. Personal communication, June 09, 2014

⁶⁶ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

⁶⁷ NRC (Nuclear Regulatory Commission), DOE. Personal communication, April 21, 2014; and Judicial Security Division, United States Marshals Service (USMS). Personal communication, May 05, 2014.

- Consider less complex security designs, as more functionality tends to be associated with increased maintenance activity.⁶⁸
- Include estimated maintenance costs in life cycle planning activities (pre-acquisition).⁶⁹
- Review documented lessons learned outlined in barrier review reports.^{70, 71, 72}

A.2.10 Training

Most manufacturers recommend operator training for active barrier systems, and all interviewed industry persons offer training (e.g. to third parties upon request or designated agents abroad, some have provided it to interested clients). Operator training prevents serious injury and legal liability, as well as equipment damage caused by improper operations. If a manufacturer does not provide a thorough program for operator training, or if barrier operation differs across a site, the user should develop the appropriate checklists and written procedures for normal and emergency operating procedures (DOE, 2005). Training should include initial and ongoing, periodic training as personnel changes are made and system features are changed.⁷³

A.2.11 Other

Additional recommended practices that do not fit neatly under the criteria categories or other topic areas include accommodating changes in threat or site conditions over time, and selecting manufacturers.

Selection of Manufacturer. The vehicle barrier industry is primarily unregulated. While there are a variety of testing standards and selection criteria (e.g., UFC, DOD, IWA, DOS, ASTM, ISO, PAS), there are no overarching federal statutes or formal policies that direct or control users in their choice of vehicle barrier or manufacturer. Even still, the choice of manufacturer is an important step in the barrier selection process. The most important consideration echoed by interviewees was to determine if the manufacturer (or general contractor, site security consultant, installation contractor, maintenance contractor, etc.) has prior experience in relevant contexts, i.e. matching special site or operating considerations. Recommendations from interviewees^{74,75} and the literature suggest selecting manufacturers that meet one or more of the following:

- Are listed as approved manufacturers from credible sources such as the DOD or CPNI. Such listings only verify documentation that the manufacturer tested the barrier as

⁶⁸ General Services Administration. Personal communication, 24 June 2014.

⁶⁹ General Services Administration. Personal communication, 24 June 2014

⁷⁰ General Services Administration: Edward A. Garmatz Federal Courthouse Dsc1200 Em Barrier Review

⁷¹ General Services Administration: Camden Federal Courthouse Barrier Review

⁷² General Services Administration: Trenton Federal Courthouse Barrier Review

⁷³ Avon Barrier Company. Personal communication 11 June 2014.

⁷⁴ This recommended practice may exclude relevant (less experienced) manufacturers. This recommended practice emerged in response to concerns with the variation in manufacturer quality and experience and resulted in a range of practices intended to identify the experience and qualification of the manufacturer in relevant site specific contexts.

⁷⁵ Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

advertised, and provides some additional information. It is necessary but not nearly sufficient to determine if the manufacturer (or barrier) is suited to a project.

- Have obtained industry performance certifications such as the International Standards Organization (ISO) 9001 standard or the Perimeter Security Suppliers Association (PSSA) verification scheme. Such listings only verify that the barrier has met some good manufacturing practices or standards. It is helpful but not nearly sufficient to determine if the manufacturer (or barrier) is suited to a project.
- Can provide a list of references from satisfied customers or otherwise provides a documented history of operations for its installed products in a similar environment.
- Demonstrate a history of manufactured or installed (depending on the service offered) AVBs of the same types that are of interest to the potential user, for an acceptable number of years. Some suggested acceptable experience as anywhere from two to five or more years.
- Demonstrate a history of manufactured or installed (depending on the service offered) AVBs of the same types that are of interest to the potential user, for an acceptable number of installed AVB units.
- Demonstrate experience with integrated design (i.e., experience with all aspects of barrier system, including upfront planning activities, installation, and maintenance).⁷⁶ Otherwise, solicit additional input or consider another manufacturer (or general contractor).
- Demonstrate barrier reliability in a relevant site context by: providing comprehensive reports of its products as tested in relevant contexts by a trusted third party; offering extended warranties (more than 2 years);⁷⁷ passing performance verification test (PVT), and an opposite season test where temperature at the site dips to below freezing (UFGS, 2009).

Change in Threat. Temporary solutions to a change in threat should be introduced and planned for during a comprehensive site design (GSA, 2007). Temporary or surge capacity should be planned for when the barrier is not in place or sufficient protection, such as during barrier installation, times of elevated threat, or after an incident (provided the barrier does not remain operational). Furthermore, following an incident, an operational capability needs to re-establish as quickly as possible (CPNI, 2014). Appropriately sized jersey barriers, or vehicles (e.g. trucks, heavy duty construction vehicles) parked at the entrance have been used in the past as temporary measures capable of preventing a speeding vehicle from entering. This temporary barrier system must be capable of protecting the compound 24 hours per day/7 days per week until the new barrier is in place (DOS, 2014).

The New York City Police Department (NYPD) has a number of recommendations for protecting high risk buildings in urban areas where there is very little standoff achievable. The recommendations of particular note are those focused on perimeter security and access control

⁷⁶ General Services Administration. Personal communication, 24 June 2014

⁷⁷ Marshalls Street Furniture. Personal communication, 25 June 2014.

(NYPD, 2009). An additional NYPD recommendation is to consider VBIED (Vehicle Borne Improvised Explosive Device) blast impact on barrier and standoff, because barriers can become projectiles that harm personnel and facility façade.

A.3. Trends and Tradeoffs

This section outlines trends and tradeoffs in AVBs. The first section describes general trends and tradeoffs. The next section describes cost specific trends and tradeoffs.

A.3.1 Cost Control: Trends and Tradeoffs

This section discusses the components of cost that impact the life cycle cost of a barrier, and does not benchmark what a barrier “should” cost. There are a couple of things to understand when costing a barrier. First, reasonable consensus exists that employing active vehicle barriers is expensive (relative to manual, passive barriers, or some site design options) and should be avoided when possible. Second, barriers often require or affect surrounding security and safety features (e.g. use of lights, cameras, etc.), and so the barrier should be costed as an access control system. Third, the barrier should be costed as a whole or total life cycle cost estimate (LCCE) because equipment alone for an access control system can be a small part of the total cost to the customer. Fourthly, the costs associated with vehicle barriers varies widely across projects and over time as technology advances continue to both increase and decrease cost (reduce installation time, maintenance levels of effort, etc.). Therefore, cost should be reconsidered for every barrier selection – do not rely on “rules of thumb.”

Recommended practice is to estimate life cycle cost for each project. Too many factors impact the cost of barriers to attribute a change in cost between projects to a specific driver and reliably generalize cost. For example, a wedge may typically cost more than a bollard. However, a shallow wedge may cost less than a deep foundation bollard due to lower installation cost and maintenance typically associated with shallow foundations. *However*, the shallow wedge may require replacement of the foundation following accidental impact, increasing cost. While it remains a challenge, suggestions to more reliably estimate cost in advance included:

- Discuss life cycle costs with manufacturers. The manufacturer’s estimate can be helped by discussing commonly overlooked cost components, clearly communicating the intended use of the barrier and operational requirements that might affect cost, and providing site visits.
- Formalize processes that encourage use of life cycle cost estimates in the planning and selection stages. Structure contracts or planning activities to integrate entities and activities across the entire lifecycle (e.g. acquisition, installation, maintenance, removal), seek extended warranties and maintenance contracts up front (rather than after purchasing a barrier), take a turnkey approach.

Estimating the life cycle cost is supported by understanding what costs too include. Beyond the cost of the barrier itself, there are barrier costs associated with pre-selection planning (cost to conduct threat/risk assessments, site surveys, and site security design), installation, operations and maintenance (O&M) (including following accidental impact), and removal or replacement.

Decreases in the AVB expected barrier life (which varies by frequency of operation, traffic weight/speed, and environment) and increases in the use of options or accessories (e.g. safety, security, and weather protection features to ensure performance) are significant and variable cost factors that are often overlooked as well. The following provides examples how costs increase across use of active vehicle barriers:

- Active vehicle barriers are on the order of 10% of the total cost for outfitting new entry control facilities (ECF), because of the need for surrounding features such as facilities and lighting. Two examples provided estimated the cost for new ECF at \$2M and \$5M (SDDCTEA, 2006).
- O&M cost can be almost as much as the barrier equipment cost. RSSI estimated the 10 year life cycle cost for two barriers, and compared the cost of the barrier, installation, integration, operation and maintenance. They estimated O&M cost (20-48% of LCC) was almost as much as equipment cost (27-52% of LCC) (RSSI, Total Cost Comparison).⁷⁸
- Installation cost can be greater than 20% of the barrier equipment cost. Of costs for equipment found (28 examples identified), the median equipment cost was about \$28.9K (USD), while of costs found with both equipment with installation cost together (21 examples identified), the median cost was about \$71.5K (USD) (See Figure A.3.1). (Sources are as listed in Table A.3.1 and (RSSI, Total Cost Comparison)).
- Cost of installation is higher if the roadways must be closed, and if utilities must be relocated (e.g. water lines), if site does not match as-tested conditions (e.g. site and design be assessed). Cost of removing or replacing a barrier can be almost as much as cost of installation, in particular if the foundation must be removed.
- Adding options to an individual barrier can quickly increase cost (although potentially necessary to ensure performance, safety, security). Table A.3.1 provides example options and an approximate added cost (quoted prices will likely differ).
- Each increase in crash rating, between otherwise like barrier models, can increase cost of the barrier equipment by ~10%.⁷⁹

⁷⁸ Assessment performed in house on two wedge models of like crash rating. Assumed maintenance performed according to manufacturer manuals. Assumed planning-factors for cost of man-hours of \$85/hr and excluding corrective maintenance for hydraulic barriers. Assumed a ten year life. Assumed equipment prices as quoted in GSA Advantage.

⁷⁹ APT Security Systems, Broughton Controls, and Highway Care. Personal communication, June 10, 2014.

Figure A.3.1. Example costs for single active vehicle barrier.

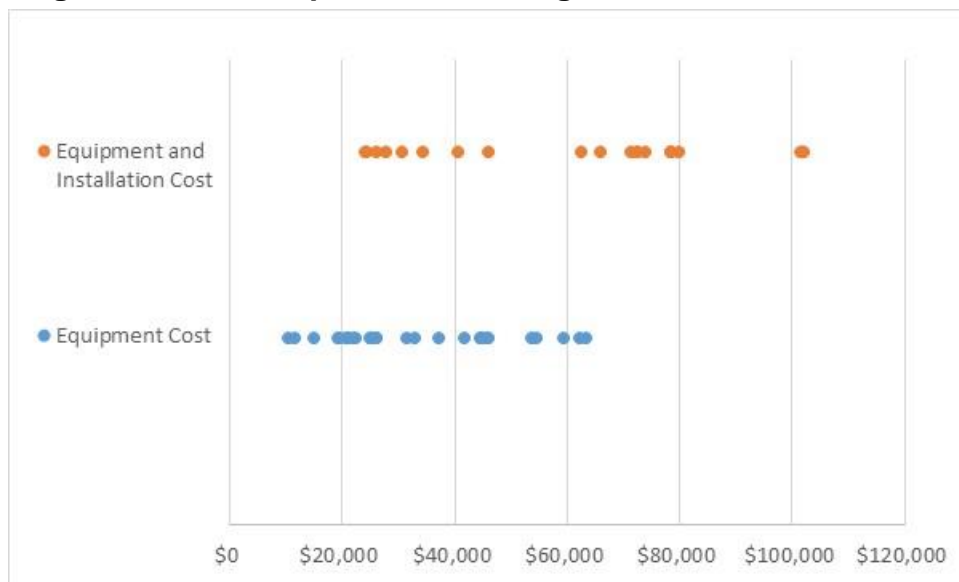


Table A.3.1. Example options and prices.

Description of Optional Feature	Cost (USD)
ODDS (Over speed Directional Detection System) package. Includes PC with monitor, interface panel, software, and relays to support up to eight sensors, flexible power supply. ^C	\$11,698
CCTV Camera on pole ^A	\$11,129
Gate Accessory, Auto Open/Close ^E	\$10,913
Ramps for portable barrier ^C	\$10,779
Gate Accessory, Keypad ^E	\$7,276
Automatic Barrier Arm (not crash-rated) ^D	\$7,254
Automatic Barrier Arm with 12' Arm ^F	\$6,236
Battery Back Up System ^F	\$5,504
Battery Back Up System ^D	\$4,467
Battery Back Up System ^F	\$4,441
Hot Weather Package ^F	\$3,482
Barrier Heat Grid System ^D	\$2,552
Cold Weather Package ^F	\$2,494
Operator Heater (HPU Enclosure) ^D	\$334
Heater kit with thermostat, 120VAC (for SA, SR, HL) ^B	\$252
Emergency Fast Operation ^D	\$6,126
Emergency Fast Operation ^F	\$2,494
Touch Screen Control Console ^F	\$2,893
Remote (RF) Operator Control System ^F	\$1,335
Hard wired push button control ^C	\$837
Additional Push Button Remote Operator Console ^F	\$763
110 Volt Adaptor ^C	\$1,000
Traffic Control Light (LED) Assembly ^F	\$1,705

Description of Optional Feature	Cost (USD)
Traffic Control (LED) ^D	\$1,008
Traffic Signal, 2 section, 8" – RED / AMBER ^D	\$793
Crash Rated Beam Flashing Light Kit ^D	\$542
Annunciator Horn – 100dB at 10' ^F	\$320
Traffic Signal Mounting Pole (4') with Pedestal Base ^D	\$313
Traffic Control Post ^D	\$202
Crash Rated Beam Magnetic Lock ^D	\$1,646
Detector, vehicle, loop wire ^B	\$231
Vehicle Loop Detector – Safety / Reset / Free Exit ^D	\$219

Sources:

(A) www.wbdg.org/ccb/VA/VAPHYS/va_security_costs_dm.pdf

(B) www.gsaadvantage.gov/ref_text/GS07F0599X/0MA9JI.2Q15H0_GS-07F-0599X_FDCFSPPRICELIST102913.PDF

www.gsaadvantage.gov/ref_text/GS07F5792R/0MRTBI.2T9QOL_GS-07F-5792R_2.PDF

(D) www.gsaadvantage.gov/ref_text/GS07F6097P/0HO5DK.24P41V_GS-07F-6097P_SECUREUSATSCSOCT09.PDF

(E) www.gsaadvantage.gov/ref_text/GS07F9574S/0J4O5J.29MGFR_GS-07F-9574S_SOASCHEDULE084TEXT.PDF

(F) www.gsaadvantage.gov/ref_text/GS07F0585W/0LI8R6.2LESGA_GS-07F-0585W_GS07F0585WCONFEDERATEGROUP.PDF

In addition to estimating costs, some current practices control costs by making decisions that positively impact cost during the planning and specification processes. There are a number of tradeoffs and considerations that can aid users in controlling costs, including considering:

- Use of site design and passive barriers. More costly and susceptible to tampering, use of active barriers should be minimized. Depending on the specific features of the site, there may be opportunities to alter the site in such a way that precludes the need for a vehicle barrier. For example, traffic calming features can be integrated to minimize vehicle approach speeds. Or, physical features of the site (natural terrain features such as trees, bodies of water, ditches), can serve as barriers. Another option is to use removable passive (vice active) barriers, use manually operated barriers, and minimize the number of entrances requiring active vehicle barriers, where such barriers maintain the desired protection levels and traffic flow. The expectation is that reducing traffic flow and the number of control points will increase security and lower the overall cost of the system (RMIA and JBS, 2009).
- Maintenance. There has been a recent trend to develop barriers that minimize maintenance requirements. Additional recommended practices, trends, and tradeoffs associated with maintenance are further discussed under the maintenance heading of this report.
- Installation. Like maintenance, installation can be a significant portion of the overall lifetime costs associated with vehicle barriers. Under budget constraints users may reduce costs through the use of a third party (i.e., someone other than the manufacturer) to install

vehicle barriers.⁸⁰ If this approach is taken it is important for users to review the installation recommended practices in this report. To reduce the number of construction events, prior to installation discuss with the manufacturer how the site or desired barrier features may change, and how the barrier will be moved, replaced, or refurbished. This may lead to adding some features or adapting the design during installation to make the barrier more transformable or modular later on.

- Replacement and refurbishment. Users need to plan for technology refreshments early on and ensure that contracting mechanisms and ownership allow for these refurbishment activities. Discuss the expected barrier lifetime specific to your site, as barrier life varies by factors such as frequency of use, traffic type, operating environment, installation quality, and level of maintenance. Because there is a significant cost associated with replacing vehicle barriers, some have considered refurbishing or extending the life of the barriers with a variety of upgrades instead of replacing the barrier.⁸¹ Refurbishment activities may involve updating control systems or responding to changing certifications or standards. Additionally, users will need to involve certified engineers to continue to assess and revalidate the performance of the barrier system over time as these refurbishment activities are executed. Modularity, above ground, or easy access to components are factors that can decrease costs attributed to the need for special equipment and additional required man-hours.
- Cost associated with increased protection level desired (e.g., impact condition designation (K and M values) and penetration rating (L and P values)). One security expert suggests that in some situations it may not be necessary to purchase the barrier with the highest protection level. Instead, he suggests calculating the approach speeds at all perimeter locations (not generalizing a single rating to be used across sites) (Norris, 2012).⁸²
- Protection and Standoff. Vehicle barriers should be placed as far from the building as possible to ensure the maximum standoff distance from a bomb-laden vehicle. It also potentially allows for greater penetration, and therefore, consideration of lighter weight or less rigid barriers. The ISC describes the general trends and relationships between standoff and the cost of protection to implement the security design criteria (including costs depending on perimeter length and type of construction) (Hall, Douglas).
- Impact condition and weight. There was a general trend towards increasing barrier weight to meet crash rating (i.e. over designing). However, manufacturers perceive a trend towards lighter barriers as they have found that much lighter than expected designs can perform to crash ratings, and result in savings in installation and removal.⁸³
- Cycle test and other requirements. At the inception of the vehicle barrier industry, users described their needs in more general terms and included fewer performance-related specifications. This resulted in vehicle barriers that were sometimes substandard. Over the

⁸⁰ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

⁸¹ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

⁸² OBO/CFSM/SM/SCD/SEB, Department of State (DOS). Personal communication, March 20, 2014.

⁸³ ATG Access LTD. Personal communication, June 04, 2014; Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

years, users have become more specific in their requirements. More intensive testing requirements impact the cost to manufacturers. The cycle test, which bares an additional cost burden, requires that barriers complete a specific number of cycles before failure. The trend toward developing safer barriers may have a similar impact on costs for manufacturers as well. See the recommended practices section on safety for more details.

- Use of non-proprietary barriers. The US Department of State and UK (CPNI) design their own non-proprietary barriers, which may offer potential cost savings as an alternative to commercial manufacturer barriers (RMIA and JBS, 2009).⁸⁴
- Other. Additional considerations for cost control include: introducing traffic calming features, reducing the number of entrances that require active barriers, minimizing aesthetic considerations, and considering integration with all other security features (not just barriers) during the planning and design processes (Kessinger, Richard). Other tradeoffs on protective measures to balance cost and effectiveness can be found in *Anti-Vehicle Barriers for Public Transit. Recommended Practice (APTA. 2012)*.

A.3.2 General Trends and Tradeoffs

The vehicle barrier industry has changed in a number of ways since the 1980 timeframe). A number of general trends follow, organized by topic area.

- Threats. Trends in threat are threat surges, expeditionary or temporary threats, small VBIED (Vehicle Borne Improvised Explosive Device) and/or dismounted attack, and the use of multiple attack vehicles or complex attack such as vehicles throwing ramps over the barriers as a way to hurdle the barriers.⁸⁵ As a result, organizations have included such threats in risk assessment methods and considered the potential impact on countermeasures, such as use of expeditionary units for emergency use; planning for rapid restoration of operational capability; conducting training that incorporates scenarios with these threats and information from test reports that document likely barrier damage; and requirements to repair or options for continued performance against a follow-on threat. As new construction materials and alternative installation methods emerge, it has been possible to use shallow or surface mounted barriers in these situations (as they may be installed more rapidly).
- Integrated design. In response to the user community looking to simplify barrier operations, there is a trend toward creating an integrated approach to AVB design.⁸⁶ This approach integrates all barrier components into a single box (e.g., have all components communicate to one another even if they are developed by multiple manufacturers). This holistic approach to design of AVBs is challenged by proprietary software and other components.⁸⁷ Interviewees echoed the need for integrated approaches to security design

⁸⁴ CPNI. Personal communication, September 11, 2014.

⁸⁵ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

⁸⁶ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

⁸⁷ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014

to facilitate ease of installation, maintenance⁸⁸ and procurement strategies.⁸⁹ For example the Virginia Department of Transportation (VDOT) described its 10-year history of using a single security contractor to support its installation and maintenance activities and involving the contractor early in the design phase.⁹⁰ The benefits of this integrated design-build approach (and the employment of security consultants) is also described by VDOT contractors.⁹¹

- Technology integration. As technology advances, it is typical for different industries to integrate, where possible, the newer technology into existing (and new) systems to support ease of use and operating efficiency. Sometimes technology integration may lead to negative impacts that users have to address. For example, some interviewees noted difficulties associated with the integration of touch-screen and wireless technology.⁹² Some AVB operators mistakenly activated barriers due to the sensitivity of the touch screen. Users found it necessary to combine the touch screen technology with push-button or other control features to minimize this error. Similarly, for wireless technology there were inadvertent activations that required the user to reconfigure the controls (for safety and security reasons). Degree of automation should be selected as to not compromise the desired level of security.⁹³
- Environmentally friendly as a selection consideration. Minimal impact on the environment (green) and minimal power usage are becoming more of an interest in the barrier industry (also technology changes contribute to the increase in use).⁹⁴ Hydraulics have made improvements, e.g., widely employing biodegradable oils, to enable them to be compliant with regulations.
- Growth in safety considerations. Active vehicle barriers have the potential to harm operators or innocent motorists when operated improperly, activated inadvertently, or designed without an appropriate set of safety features (safety detection loops, presence markings/warning signals, etc.). In a continued effort to address safety concerns surrounding active vehicle barriers, an interviewee noted that some manufacturers are developing barriers with non-lethal and other similar safety claims.⁹⁵ Typically, these are non-rigid barriers (e.g. nets) designed to reduce the accelerations associated with the vehicle-barrier collision. However, currently, there is no formal standard associated with what acceleration level is acceptable to ensure motorist safety. Additionally, validation testing to confirm safety claims or to determine the level of safety that an AVB provides to innocent motorists only exist for longitudinal barriers for use on highways; FHWA did not design the methods for use in testing active vehicle barriers. Introducing validation testing

⁸⁸ Physical Security Abroad (CSN), Personal communication, 10 June 2014.

⁸⁹ General Services Administration, Personal Communication, 24 June 2014.

⁹⁰ Virginia Department of Transportation (VDOT). Personal communication, 13 June 2014.

⁹¹ Elite Constructing Group. Personal communication, 19 June 2014.

⁹² Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

⁹³ Avon Barrier Company (ABC). Personal communication, 11 June 2014.

⁹⁴ Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

⁹⁵ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

specific to safety could potentially increase cost to manufacturers that is passed on to buyers. These and other similar issues are topics being considered in ASTM F12 subcommittee meetings.

- Growth in barrier post-impact condition considerations. The barrier's survivability post-impact is of growing concern due to the increased vulnerability of the barrier to a second attack. An effective barrier must have the ability to absorb the energy of the impact to its foundation. There is no current method or testing to validate a crash rating for barriers post-impact (for actual incidents). However, some laboratories, e.g. those testing to ASTM and PAS68 standards, have been documenting barrier features post-impact during the initial crash testing and including those details in their reports. Following an incident, participants in the April 2014 VBWG meeting recommend recertification of barriers. It was noted that a good practice would be to hire an accredited engineer to reassess and inspect the barrier post-incident to determine repairs necessary to retain crash rating.
- Smarter barriers. Barrier systems are incorporating new features (e.g. sensors) that support an increased capability to monitor system health, detect intrusion, security, safety, and communications. Some smart barriers also include sensors to alert when maintenance is required, when the barrier is not operating, to log maintenance performed, to log number of barrier cycles (use), and to detect unintended intrusion or compromise of the barrier. Other sensors can detect vehicle speeds and loads. New technology features for detection and communication can contribute to ensuring performance in a wider breadth of DBT/operational contexts. However, users should weigh potential security vulnerability concerns that can result from this type of technology. Some are also web addressable to facilitate immediate reporting, ongoing monitoring by manufacturer support, or remote operation. However, this is often prohibited in high security contexts due to the risk of hacking to the operating system (i.e., introduces a cyber-vulnerability).
- Advances in software. Software programming and integration into active vehicle barriers has advanced to make it simpler to build systems of systems (e.g. to include multiple barriers and in integrated security control) that support intelligence and also to allow specificity in controls (e.g. multiple operating modes). Cutting edge software can enable qualified staff to modify the system to satisfy unanticipated requirements (e.g. addition of new barriers or sensors). Emerging guidance has begun to address software, e.g. interoperability.
- Barrier type—electric. In part to reduce maintenance activity and cost, there has been increased use of electric/electromechanical barrier types.^{96,97,98,99} These (electric) styles now demonstrate operating speeds comparable to those of hydraulic units. While reductions in maintenance are being advocated, the quantitative reductions are still in the process of being documented and demonstrated.

⁹⁶ Architect of the Capitol (AOC). Personal communication, April 11, 2014.

⁹⁷ Robotic Security Systems Inc. (RSSI). Personal communication, April 15, 2014.

⁹⁸ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

⁹⁹ OBO/CFSM/SM/SCD/SEB, Department of State (DOS). Personal communication, March 20, 2014.

- Barrier type—styles. There is no clear trend in styles, it tends to be a preference by country or organization based on availability or personal experience with styles, or upon site constraints that create a preference in a specific instance. More users prefer bollards in areas where aesthetics or pedestrian access is important. Some users have migrated to barriers with above-ground components (despite some aesthetic preferences against) to avoid maintenance and drainage or freezing.^{100,101,102} Some prefer nets (or less rigid barriers) because of perceived reduced risk to innocent motorists (less G force upon impact). However, as manufacturers continually improve on existing technology, simple technology-based rules may not apply and can unnecessarily restrict selection. For example, while many gates can operate too slowly, bi-folding gates can attain higher operating speeds.
- Barrier type—shallow or zero excavation. More barriers styles are available as surface (on platforms, bolted, or pinned to foundations) or shallow (not defined, roughly less than 48 inches¹⁰³) foundation barriers. The trend to use shallower depths for barrier installation may in part be driven by organizations that are expending effort to better understand structural foundations. For example, CPNI is working with industry and impact test facilities to support identification of new materials and alternative construction methods (CPNI, 2014). They have been favored for urban areas or leased facilities to avoid interfering with underground utilities. Opinions on cost trade-off are mixed and life cycle cost comparisons are recommended. Deep foundations can (but not always) remain less expensive despite the lower installation cost of shallow foundations. This is because shallow foundations can be more expensive to repair following accidental impact, if their survivability is low.¹⁰⁴
- Temporary or portable barriers are subsets of shallow barriers that are additionally easier to transport, remove, or redeploy. Expeditionary is used to indicate especially quick deployment. The advantage to these barriers is that they can be deployed at times of heightened threat, or for periodic events, without the need to invest and maintain year-around barrier performance. Recent advances in technology and testing activities have decreased some, but not all challenges typically associated with temporary barriers. What has improved is an increase in the variety of styles available as portable or temporary models, reduced install time and use of specialized equipment, additional crash ratings comparable to permanent barriers, and (sometimes) tested or designed to deploy on soft ground (e.g. soil). What remains a challenge is that their deployment is still based on adequate advance intelligence of the threat level (CPNI pp 28, 2012). Unless otherwise specified, most temporary barrier designs are not intended for unmonitored or unstaffed locations, or for use with many accessories. They are not designed for permanent use, although they can be with greater installation cost to modify the barrier (ramp, etc.). Installation on unknown substrate requires additional work.

¹⁰⁰ American Society for Testing and Materials (ASTM). Personal communication, April 21, 2014.

¹⁰¹ Air Force Civil Engineer Center (AFCEC), Naval Facilities Engineering Command (NAVFAC), and US Army Corps of Engineers Protective Design Center (USACE PDC). Personal communication, April 10, 2014.

¹⁰² OBO/CFSM/SM/SCD/SEB, Department of State (DOS). Personal communication, March 20, 2014.

¹⁰³ The GSA Site Security Design Guide defines shallow-mount perimeter systems as those that require less than 18 inches of below-surface depth (GSA, 2007).

¹⁰⁴ Avon Barrier Company (ABC). Personal communication, June 11, 2014.

A.4 Operational Considerations

Historical examples of AVB incidents (e.g., events such as impact or failure in the field) demonstrate potential problems or failures, but also serve to illustrate successful employment of barrier systems. Most incidents characterize barriers' ability to prevent or delay a violent attack, to operate effectively to control traffic, and to deploy only when intended.

A violent attack is a rare event. Most examples of a barrier being hit resulted in denial of the vehicle. However, like all man made defensive systems attacked by overwhelming force, AVBs can be breached. Breaches have been attributed to poor barrier design, where vehicles pass over or under arms, or a lack of continuous perimeter, where vehicles drove around barriers. In historical examples of catastrophic attack, aggressors using powerful vehicular borne explosives have completely destroyed barriers. In cases where breaches were made, a "layered security" or "defense in depth" posture and an effective overall security plan allowed organized personnel to quickly detect and thwart the overall attack. In these cases interior facilities and personnel were saved from destruction.

Barrier failures under normal operating conditions were characterized as both unintentional opening and unintentional closing. Based on a review of incidents, most errors were attributed to a lack of proper maintenance, installation, and poor operator training, which is reviewed in more detail above and will not be repeated here. All (except perhaps human error) incidents appeared to be preventable. However, a more realistic attitude is to expect that the barrier will be subject to operating conditions outside of normal operations, e.g. subject to accidental motorist impact, weather, wear, errors in operation, installation, or maintenance.

Rather than relying on "fool proof" barrier design and operation, include measures in specifications, service contracts, and operating procedures that maximize detection of barrier problems and minimize cost and time to resume normal operations. A few examples of ways to ensure continued operation are to:

- Define the intended function or operating procedure of the barrier and associated features when determining operating procedures during site design. Ensure operational procedures and potential barrier designs are tweaked to complement one another. In several examples the intended operating procedure and site design did not allow for the proper performance of a barrier. For example, while the barrier functioned correctly, obstructed line of site and improper sequencing of components led to trapped vehicles. Interviewees believe those errors could have been avoided with a better understanding of security operating procedures (not just of the blocking component), communicated to manufacturers and installers. For example, while the barrier could facilitate higher traffic flow, the site design could not accommodate lengthy searches or rejection of vehicles. The DOD SDDCTEA (Army Surface Deployment and Distribution Command Transportation Engineering Agency) and USACE PDC (US Army Corps of Engineers, Protective Design Center) continue to publish examples of schematics and operational procedures that complement barrier operation. Tweaking operations to fit barriers can also compensate for a barrier's operational risks. Singapore described an operational change to release

vehicles that had been checked by batch, so that cleared vehicles would then form a natural barrier to prevent any intruding vehicle from attaining crash speeds.¹⁰⁵

- Establish plans not only to prevent incidents but to have plans in place to efficiently detect and respond to barrier malfunctions. Detecting errors in barrier performance or in operating procedure is difficult. Oversight, training, and maintenance are process points where detection capability can be increased. One group had success training operators to observe and report potential maintenance needs that often go unreported (e.g. debris). Ensure that operations during emergency procedures and following accidental impact are understood as well.

Accidental barrier activation has caused injuries to personnel and equipment during what were considered routine operations. Some have prevented unintentional activation by:

- Enforcing operating procedures (operator/organizational error). A number of accidents have occurred due to operator or organizational negligence associated with poor training, accidental barrier activation, violation of procedures and policies, and ineffective procedures and policies.
- Increasing accountability by installing over-watch (e.g. cameras)¹⁰⁶ or removing remote operation capabilities.¹⁰⁷ Some do not allow automatic opening or remote operation to remove the risk of accidental deployment and tampering. Those that have found remote features useful recommend use of cameras to keep a human in the loop.
- Including redundant features, and/or a human-in-the-loop during operation. One option is to include redundancy that reduce risk of being confounded (e.g. by forged license plates, presence of fog, low metal content of vehicles, presence of debris). A second option is to make activation more intentional, e.g. by locating buttons away from each other or using a two stage activation.

¹⁰⁵ Protective Security, Ministry of Home Affairs, Singapore. Personal communication, June 09, 2014.

¹⁰⁶ Vehicle Barrier Working Group (VBWG). Personal communication (meeting notes, unattributed), April 14, 2014.

¹⁰⁷ Avon barrier Company (ABC). Personal communication, June 11, 2014; ATG Access LTD. Personal communication, June 04, 2014.

APPENDIX B. METHODOLOGY

This appendix provides technical documentation of the methodology employed to produce a series of products that support specification and selection of crash-rated, active vehicle barriers (AVB) (also referred to as Power Assisted Vehicle Barriers, or PAVB). To produce the deliverable, the study team conducted the following activities:

- Developed an analytical framework. Battelle defined selection criteria to describe the set of considerations that people commonly include when specifying and selecting active vehicle barriers, based on published guidance. Battelle identified a subset to include as searchable criteria in a spreadsheet, based primarily on the availability of data within manufacturing specifications. DOS and TSWG reviewed and approved the selection criteria.
- Gathered and analyzed data. To identify sources of data, DOS and TSWG provided an initial list of documents and members of the AVB community. A review of the literature and open internet searches identified additional potential sources of data. DOS, TSWG, and Battelle selected a subset to interview. Defined and identified recommended practices. Compared documents and identified where census or conflict occurred.
- Published products. This included methods to write, review, and disseminate the final products, as well as to provide supporting briefings or documents to TSWG as needed.

DOS and TSWG provided project oversight through a series of scheduled in-person meetings (in progress reviews), monthly reports on study progress, and additional meetings as requested by Battelle to inform or review draft deliverables.

B.1. Develop an analytical framework

DOS and TSWG defined the scope to include a subset of vehicle security barriers (VSB), namely, those that are both active (called power assisted vehicle barriers (PAVB) or active vehicle barriers (AVB)) and crash-rated.

Battelle, in coordination with TSWG and DOS, defined assumptions within a study plan that was refined by DOS and TSWG during the initial, kick-off meeting. Given the large number of operational, functional, and other considerations that impact AVB selection and design, the study team identified the most significant criteria that users might consider. This assumes that users have defined their needs to some degree:

- Identified a design basis threat (DBT) or conducted other similar vulnerability/risk or threat analysis to define the threat(s) for which the barrier system will address, as well as acceptable risk and desired levels of protection.
- Conducted site surveys (design phase) and other assessments and analyses (e.g., bomb blast analysis, vehicular and pedestrian traffic flow studies) to better understand building characteristics (response, post-impact condition, and recovery/functions and infrastructure analysis) and community context (e.g., utilities and roadway infrastructure), both of which impact an overarching security plan that includes vehicle barriers.

- Incorporated environmental and weather considerations into the design of the current approach road(s) where the vehicle barrier(s) will be located.
- Reached a phase in their vehicle barrier selection process that warrants search for the specific types of vehicle barriers found in the Model Specifications Spreadsheet—bollards, rising wedge, beam and cable, drop arm, and swinging/sliding gate systems.

Battelle also defined some terms of reference, including what would be considered a crash-rated, active vehicle barrier and internal terms to clarify analytical products (e.g. recommended practice). (See Glossary and Section 2 for the complete definitions and terms of reference).

The intended end user for products was defined by DOS and TSWG. They identified that document content and language should support use not only by engineers, but also non-engineers (policy makers, security managers, or intelligence analysts that affect the decision making process), and/or individuals less expert in AVB selection. Furthermore, that users may originate from the private sector or all levels of government, including municipality and city, CONUS, or OCONUS. This led the design of deliverables away from highly technical or context-specific documents and towards documents that included introductory material that heavily referenced more detailed documents or tools suitable to specific conditions.

The study timeline of approximately seven months led to additional decisions to make products (1) tightly focused in scope, (2) comprised of readily available data, (3) stand-alone products capable of being widely disseminated “as-is” and (4) not a living document.

Battelle derived an analytical framework to identify the breadth of potential specification considerations, collectively referred to as selection criteria. Battelle identified selection criteria from multiple existing descriptions of selection considerations, primarily APTA SS-SIS-RP-009-12 (APTA, 2012); CPNI Guide to Producing Operational Requirements for Security Measures (CPNI, 2010a); DOD UFC documents (UFC-4-022-02, 2009); and DOS OBO Standard Specifications (DOS, 2012). TSWG and DOS reviewed and approved the selection criteria. See the full description of resulting selection criteria in Section 2.1. Selection criteria were used in development of reference sections to ensure that efforts to gather data (e.g. prompts to interviewees) was comprehensive.

B.2. Gather and analyze data

Battelle gathered data for the References through a literature review and interviews with subject matter experts (SME). To identify sources of data, DOS and TSWG provided an initial list of documents and members of the active vehicle barrier (AVB) community. A review of the literature and references suggested by other SME identified additional potential sources of data. DOS, TSWG, and Battelle selected a subset of potential SME to interview.

Interviews identified recommended practices, tradeoffs, and trends (included in Reference 2) as well as useful resources and tools useful to parts of all References. Interviewees were broadly represented to include (collectively) US and non-US organizations from both public and private sectors, which had manufactured, tested, selected, employed, and/or published guidance for AVB. The final report documents the interview process by providing a list of organizations that

accepted an invitation to participate, and indicates which were interviewed or otherwise provided materials. The report also includes the list of questions provided to interviewees in advance of a meeting and employed in whole or in part (appropriate to the organization's role) during interviews to elicit information.

Data was then analyzed to either (1) compile and explain available resources, or (2) integrate and summarize experiential knowledge. The former does not require extensive analysis and is primarily at risk of excluding relevant data. To guard against that, Battelle included interview questions to identify resources and tools from SME.

Analysis of experiential knowledge required analysis of subjective and qualitative data, which in this study, typically lacked documented supporting evidence. Battelle recorded meeting and email correspondence notes to assure lessons learned could be directly attributed to sources. Battelle compiled citations from published documents and interview notes into a spreadsheet, categorized by topic areas and analytical topic (e.g. best characterized as a recommended practice, trend, operational consideration, challenge, or other). Battelle then identified any coincident or conflicting qualitative data on the same subjects. When in conflict, both conflicting lessons would be presented in the report, with distinguishing circumstances on their applicability or justification, if possible. Data was excluded from the report if comments were out of scope (did not fit a report category of interest), or were redundant to a more detailed reference that could be cited rather than reproduced in this document (e.g. some safety topics). All results included in the report were reviewed by a subset of the interviewed SME.

The specification template(s) (Section 3) was created based on a comparison of existing specification templates. The primary templates used in analysis were: the CPNI Scoping Document, USACE PDC (2008), Department of Veteran Affairs (DVA), and those provided by DOS (OBO Standard Specifications, 2012). A single document was produced by integrating common content across documents. Where document data was different, i.e., the source specifications were more detailed but the exact details differ, the differences were noted by inserting generic language that details could be "user-specified," with references to the existing specifications as examples of potential suitable measures.

For the searchable model specifications spreadsheet (Section 4), the sources used to identify crash-rated, active vehicle barrier model information came from the 2014, USACE PDC list of ASTM and DOS crash-rated barriers (USACE, 2014), a list of crash tested barriers provided by CPNI (CPNI, 2014b), and a vehicle barrier list compiled by Concentric Security LLC (Concentric Security University. Barrier Selection Tool). The Battelle team visited manufacturer websites to locate (or requested by email) publically available models specifications, brochures, and drawings. Manufacturer websites sometimes identified additional barriers that were crash-rated, or designed and engineered (but not tested) to be crash-rated, and were included as found. Given the variety of detailed information contained in specifications, the study team identified selected search criteria to include, based on their utility to facilitate queries that impact AVB selection and design, and on the availability of data in publically available documents.

B.3. Produce, review, and publish products

The Battelle team believed that the materials would benefit from having the greatest number of eyes review the documents. DOS and TSWG provided an internal review of the document first drafts. They then identified a number of external reviewers to further vet all products. The external reviewers included a representative from the USACE, AOC, CPNI, USMS, ASTM, Security Consultants (Rileen/Elite Company), GSA. External reviewers were provided with six weeks to review, a blank comment matrix to record comments, and a set of questions requesting that they comment on: presence of content that was complete (e.g. available resources were included) and correct (e.g. recommended practices were generalizable or properly caveated), use of clear format and language, and what could be done to make the products more useful to them. Battelle created a comment matrix to review with TSWG and DOS and determine how to adjudicate responses.

All manufacturers included in the searchable Model Specifications Spreadsheet were notified of the spreadsheet and intended use by email or through online contact forms as provided by the manufacturer website (or previous contact). Manufacturers were invited to review and comment on information related to their products over a six week period. Those requesting to review data were provided with a copy of the rows for their models. For manufacturers that provided edits, Battelle reviewed, resolved questions with the manufacturer, and integrated changes in to the final spreadsheet.

TSWG and DOS developed a dissemination plan for final deliverables, to include determining markings, storage and maintenance, and how to maximize product awareness and access.

APPENDIX C. INTERVIEW GUIDE

This appendix contains the interview guide provided to interviewees in advance of a telephone or in-person interview, used to elicit responses from interviewees. Two interview guides were used. The first draft was provided to interviewees through May 2014. The second draft was provided to interviewees starting June 2014. Both versions contain the same scope of topics and intent of questions. The second draft refined wording to elicit more specific examples (e.g. “do you have examples or evidence of”) and also to include a table of reoccurring recommended practices identified from early readings and interviews, both to provide an example and to facilitate census building or refinement of re-occurring themes. The following section provides the second interview guide, which subsumed items from the first interview guide.

C.1. Interview Guide 2

Introduction to what is a recommended practice.

We have included examples of general recommended practices we have heard, to give you a sense of what might be included in the report and to spark comment.

Table C.1. Example of potential recommended practices.

#	Topic	Problem	Recommended Practice	Expected Outcome
1	Planning and analysis	AVB not designed for site-specific features	Consult with a variety of experts and conduct supporting analyses to plan site security and AVBs in a holistic manner	Avoid unnecessary costs associated with selection of inadequate barrier or other security feature
2	Aesthetics	Barrier system seen as a negative impact on the community	Consult with experts in historic preservation and public space	Minimized impact of barrier system on landscape and community residents (noise levels)
3	Selection of Manufacturer	Faults with barrier	Select manufacturers with extensive positive past performance ¹⁰⁸	Quality AVB with extensive service from OEM beyond equipment purchase and installation
4	Safety	Unsafe conditions leading to incidents with innocent motorists and/or AVB operators/security guards.	Include safety in planning and design, using standards set forth in documents such as PAM 55-15; integrate safety features into AVB design	Minimize crashes, fatalities, injuries, mission distractions; protection from potential liability; help maintain efficiency of security personnel.

¹⁰⁸ This recommended practice may exclude relevant (less experienced) manufacturers. This recommended practice emerged in response to concerns with the variation in manufacturer quality and experience and resulted in a range of practices intended to identify the experience and qualification of the manufacturer in relevant site specific contexts.

#	Topic	Problem	Recommended Practice	Expected Outcome
5	Security	Barrier tampering	Locate support equipment on secure side; add tamper switches; remote monitoring	Reduce security breaches that might lead to barrier malfunction or premature deterioration
6	Installation	Malfunctions due to improper installation	For third party installers have the manufacturer present (sign-off) during installation; use certified technicians; use experts for quality assurance/oversight; extensive documentation	Less malfunctions/better quality AVB
7	Installation	AVB performance in site condition differ from testing conditions	Involve structural and other engineers in assessing site conditions and verifying structural integrity of materials	(More likely) performance expected from tested crash rating
8	Training	Operator injury, legal liability	Provide operator training, procedure manuals and checklists	Fewer incidents associated with operator error
9	Maintenance	Frequent failures with barrier components leading to high costs	Follow manufacturer's maintenance schedule; More detailed maintenance specifications and contracts; frequent inspections	Positive impact on barrier longevity; fewer replacements or refurbishments required
10	Other	Low quality AVB that only meets K/L rating	Detailed specifications	Quality AVB designed with user's unique needs beyond crash rating

Interview Guide.

1. What are the circumstances, site, or situational conditions (i.e., what decisions that are site-specific vs. standardized) that direct you to change "site-specific " aspects of a template specification? What conditions make using certain feature or styles less desirable/impossible?
2. Do you have examples or evidence of tradeoff that exist between the selection criteria you use? For example, we have heard some tradeoff exist for:
 - a. PAVB design and site design (e.g. standoff distances and penetration rating, use of speed calming techniques (altering roadways/entrances))
 - b. Cost Control and aesthetics / physical design (e.g. depth) / warranty / services /etc.
 - c. Maintenance and barrier longevity/durability (ability to withstand environmental/weather conditions)

d. Security and safety or traffic flow (e.g., features that support highest level of security but may not necessarily be the safest or most accessible to pedestrian or traffic flow).

3. Do you have examples or evidence of recommended practices in those areas or others? E.g., installation and maintenance, operator training.

4. What are the tradeoffs expected when choosing between the following vehicle barrier types (or features or drives): bollards, rising wedge, swing/sliding gate, beam and cable, drop arm. Is there any clear cut reason when one style or feature is preferred over another? Some recommended practices are to add tamper switches, CCTVs, sensors. Can you discuss specific examples where you have instituted these practices and seen positive results?

5. Can you provide examples of the types of information that would be most beneficial to include or common measures/language to use when specifying barriers (to better support PAVB specification and selection)? For example, how would you recommend standardizing content or language for maintenance items, if parts can be made common?

6. Do you have examples or evidence of factors that contribute most to lifetime costs for active vehicle barrier systems (e.g., installation and maintenance, threat level, architectural enhancements, operating system requirements, refurbishment or removal)? What special situations increase or decrease life cycle cost?

7. Do you have examples or evidence of factors that ensure quality of training over time and many barriers/styles?

Recent Trends and Developments in PAVB Models

8. What is the impact of emerging technology (drives, features, etc.) on barrier specification or employment practices? For example, there is a trend towards electromechanical. Do you have thoughts about what is driving the trend or what impact the trend is expected to have on the vehicle barrier industry?

9. Do you have evidence or example of emerging practices (e.g. integrated or holistic design) that affect barrier specification or employment? For example, there is a trend to use a separate installer or third party maintenance after warranty, as a cost control mechanism. Do you have a sense for the type of cost savings one can achieve? Is it 10%-20% of equipment purchase cost? But, is the cost saved worth the potential lower level of quality that might come from not having manufacturer representative present?

10. What circumstances decrease and increase all, or any one style of, PAVB performance? (e.g., location/environment, level/type of additional security).

Support for the Selection of PAVB

11. Are there resource you have found useful (available training/classes, guides, standards, tools, and experts/stakeholders to contact) that you recommend or would be willing to share with “newer” users trying to become an expert in the field?

12. Some guides and tools exist to help people select PAVB. Do you feel like you (or people new to the field) have sufficient resources? What type of additional resources would be most useful? For example, do you lack access to necessary technical information to compare PAVB, to distinguish which lessons learned or recommended practices are applicable to your site, or lack of tools to determine the right specifications for a particular site?

Incidents

13. Can you described specific incidents or successes that have changed the way you manufactured, selected, employed, or operate PAVB?

14. Do you have evidence or examples of operational employment of PAVBs that led to an increase or decrease in performance? In what ways does intended operational employment change one's selection of PAVB or PAVB features?